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CHEMISTRY.—*Polymer chemistry of silicates, borates, and phosphates.*[1]

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Many inorganic compounds can be considered as polymers—as a matter of fact, better understood ones than the more widely known organic examples. Prominent among these are the silicates, knowledge of which was developed from three distinct directions which converged on a single goal. These approaches were through the classifications and factual information of classical mineralogy, through the chemical study of phase equilibria, and through the analysis of crystalline structures by a generation of X-ray workers. The basic principles finally derived are here summarized as a branch of polymer chemistry without the detail of the close view (*A*).[2]

One can not take a comprehensive view of silicates without being aware of phosphates and borates as a contrasting background. Knowledge about phosphates and borates, however, is less developed than for silicates, and this will cause some gaps in the treatment. The general view has brought unknown parts to light, and the way in which explanations have developed for them is a reward of the work.

Relationships of compounds in systems containing only a few components are shown by the familiar phase diagrams, which are the summary of experience guided by the phase rule. It is reasonable to ask, "Why do particular compounds appear?"—a question outside the usual thermodynamics. The answer, which can not yet be fully given, depends in part upon a knowledge of the patterns after which the compounds are built. In the case of silicates, borates, phosphates, vanadates, etc., this is essentially an inquiry about ways in which the elementary groups polymerize to form more extended structures.

The structural element of silicates and phosphates is a tetrahedral grouping of four oxygen ions around a central positive ion as shown in Fig. 2. These groups are joined in polymers by sharing of oxygen ions between two and only two groups as illustrated by the pyrosilicates and metasilicates (Fig. 2). Closed group, chain, sheet, and spacework patterns are built up by repetition of this sharing in a variety of ways, as will be shown. Borates can also have the tetrahedral grouping of four oxygen ions around a central boron ion, but the common structural element is a triangular borate ion, $(BO_3)^{-3}$.

In any polymer of the type to be discussed the extent of polymerization can be indexed by the degree to which oxygen ions are shared between tetrahedral SiO_4 groups. Thus in the pyrosilicate group each silicon ion is surrounded by 4.0 oxygen ions but can be assigned only 3.5 oxygen ions since one is shared. The type of sharing is often, but not necessarily, indicated by the formula.

Phase relationships between silica and a second component with which it can not form copolymers are epitomized in Fig. 1. From the viewpoint of polymerization nothing essentially new is added by further components. While the effects of an ion

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[2] References are to the Appendix at the end of this paper.

such as Al^{+3} that can partially replace Si^{+4} in a group will be neglected, they too can be explained.

Increase in the silica content of a system necessarily results in formation of compounds of increasing degrees of polymerization. With low contents of silica the groups are small as in the ortho-, pyro-, and metasilicates. Metasilicates and compounds richer in silica can be infinite polymers with varieties of forms that will be described. Each polymer is structurally distinct and for this reason generally does not form solid solutions with its neighbors (*B*).

A particular compound can often exist in more than one form. In the ortho-, pyro-, and group metasilicates these forms are merely alternative ways of arranging the groups with respect to the other atoms present. For this reason the transformations are sometimes rapid ones that can be located only by cooling curves. Since metasilicates and higher polymers can form closed groups of varying complexities as well as infinite chains, crystal transitions might involve changes in polymerization. Such changes are chemical reactions and are often very slow. It is for this reason that the quenching technique has generally been used in the study of silicate systems (*B*).

Chain, sheet, and space polymers other than the limiting SiO_2 are subject to considerable breakage upon heating. This is due to their extended forms and as a result lower temperatures are often required for their formation than are necessary for orthosilicates or silica. Formation of two liquids as will later be discussed is also a result of changing polymerization.

Systematic classification of silicate minerals is chiefly determined by types of silicate polymers. Examples of the known types are indicated in Fig. 1. Occurrence of two types of polymers within the same crystal is very rare. It is here illustrated by vesuvianite, which contains both orthosilicate and pyrosilicate groups.

We now turn to consider the detailed structures of the polymers. The SiO_4 group, as previously mentioned, is the basic structural element of all silicate polymers. Its form is shown in several conventional manners in Fig. 2. In this figure the spheres represent ionic centers, the smaller being silicon while the larger is oxygen. Oxygen ions considered as spheres really have about 3.5 times greater diameters than do the silicon ions. They are shown approximately to scale in the second tetrahedral group in Fig. 2 and it is perhaps best to picture the $(SiO_3)_3^{-6}$ group in this way.

Pyrosilicate groups have been observed in the two indicated forms that differ by relative rotations of the constituent SiO_4 groups. Presence of one or the other form depends upon the surroundings in the solid since the energy difference between them is probably small.

Three types of metasilicate groups are shown in Fig. 2. The two $(SiO_3)_4^{-8}$ groups differ in the way in which the silica tetrahedra are placed. While the first of these has not yet been observed as an independent group, it is the polymerizing element in the sheet polymers of the silicates apophyllite and gillespite. The second type with alternating inversion of the SiO_4 tetrahedra has not been observed for silicates but is present in aluminum meta-

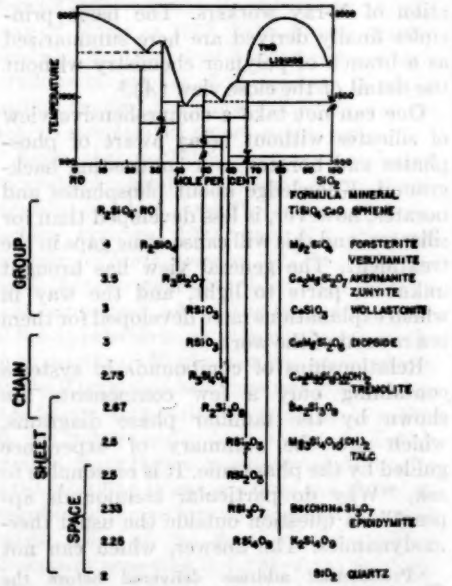

Fig. 1.—A hypothetical diagram showing the types of compounds appearing in a system, RO-SiO_2. Typical minerals corresponding to various stages of silicate polymerization are listed.

phosphate, $Al(PO_3)_3$. The $(SiO_3)_6^{-12}$ metasilicate group, which one might refer to as the hexametasilicate group, is present in the minerals beryl and cordierite. Six membered groups that are elements of sheet and space polymers have two other configurations, one of which is shown in Fig. 2.

Metasilicate compositions can also be given by infinite linear polymers, or $(SiO_3)_N^{-2N}$ chains, which are analogous to the polyisoprene chains of rubber. Solids containing this group have the expected property of forming fibrous masses or masses with lathlike cleavages. Separation of these groups from melts which contain a mixture of less extended forms is a slow process of polymerization in which the catalyst, equivalent to a peroxide for a diene, is the crystal growing from a nucleus.

More elaborate silicate polymers are illustrated by Fig. 3. The upper chain of SiO_4 groups is the chain metasilicate $(SiO_3)_N^{-2N}$, which can be doubled as above the dotted line on the left to form $(Si_4O_{11})_N^{-6N}$ chains of the type that are present in the amphiboles. The $(Si_4O_{11})_N^{-6N}$ chain or double chain, however, could equally well be considered as a polymer in which the pattern element is the 6-silicon ring $(SiO_3)_6^{-12}$ group. Repetition of this group or of the metasilicate chain, as above the line on the right, would lead first to an $(Si_3O_8)_N^{-4N}$ infinite polymer in which one-third of the silicon ions share four oxygen ions with their neighbors and the remaining three oxygen ions. While a polymer of this composition is known, it has an entirely different configuration as will be shown in the later discussion of $Ba_2Si_3O_8$.

The limit of repetition of a polymerizing pattern of the type shown in Fig. 3 would be a sheet polymer with the composition $(Si_4O_{10})_N^{-4N}$. This polymer is observed in some of the micas and clay minerals and it imparts the platy character to these substances. If two such sheets are superimposed into a double sheet then the resulting polymer will be one in which all oxygen ions are shared between silicon ions and the composition will be SiO_2. While none of the known forms of silica has this configuration, it is thought to occur as plates in one of the minerals related to kaolinite (4).

An alternative arrangement of the 6-silicon ring $(SiO_3)_6^{-12}$ group or of the metasilicate chain can be considered as the structural element in the tridymite form of silica. Repetition of the polymerizing element leads to complete space filling and we thus see the prototype for cross linking in organic polymers. Space filling is accomplished in other ways in the two other crystalline modifications of silica which will not be discussed here.

The known $(Si_3O_8)_N^{-4N}$ polymer which

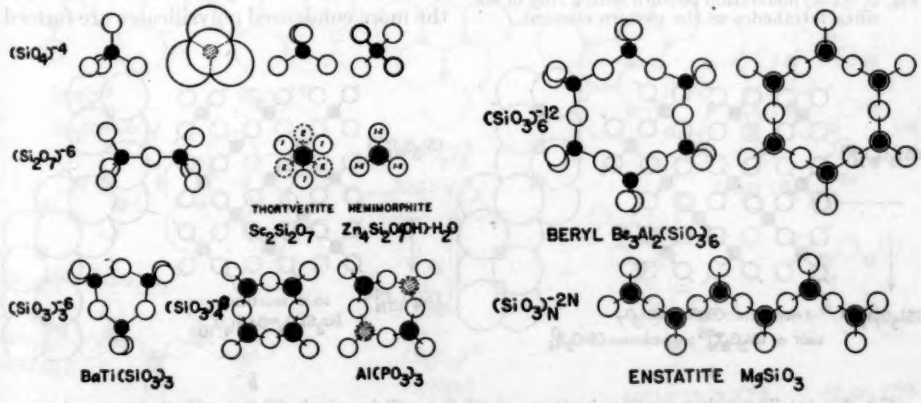

Fig. 2.—Configurations of some silicate groups. The tetrahedral $(SiO_4)^{-4}$ group is shown in the several different ways that will be followed in the various figures.

might have been formed with $(SiO_3)_6^{-12}$ as a structural element really is built up in a different way as shown in Fig. 4 (*b*). The pattern element might be looked upon either as an $(SiO_3)_4^{-8}$ group or a new configuration of the $(SiO_3)_N^{-2N}$ infinite chain. Continuation of this type of pattern leads to a sheetlike structure of the composition SiO_2. Such a form of silica, however, has not been observed.

A continuation of the $(Si_2O_3)_N^{-4N}$ polymer in which the infinite $(Si_2O_3)_N^{-4N}$ multiple chain can be considered as the pattern element is present in the mineral epididymite. This polymer is formed by sharing of the oxygen ions on the upper edge of one $(Si_2O_3)_N^{-4N}$ chain with those on a lower edge of another chain as shown in Fig. 4, *a*. The final composition is $(Si_2O_7)_N^{-2N}$.

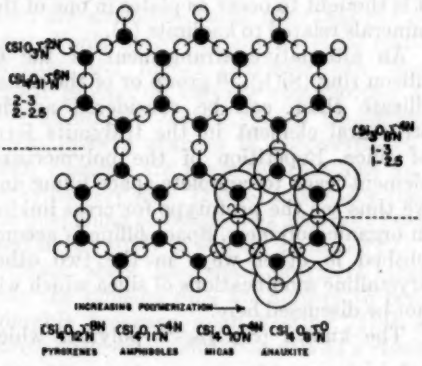

Fig. 3.—Polymerization pattern with a ring of six silica tetrahedra as the pattern element.

One of the distinctive properties of silicate systems is the general absence of solid solutions between compounds having different polymerization indices. Eskola, however, in his study of the system BaO-SiO_2 (*6*), found an exception to this rule in the formation of a complete series of solid solutions between $Ba_2Si_3O_8$ and $Ba_2Si_4O_{10}$. These solid solutions apparently result from the union of $(Si_2O_3)_N^{-4N}$ chains through the addition of SiO_2 as shown in Fig. 4, *b* (*C*). In a sense this is copolymerization of $(Si_2O_3)_N^{-4N}$ chains and SiO_2 leading to a sheet polymer having the composition $(Si_4O_{10})_N^{-4N}$ which can alternatively be reached after the pattern of Fig. 3 and in several other ways by $(P_2O_5)_N^0$ and $(V_2O_5)_N^0$.

The mineral gillespite, $BaFeSi_4O_{10}$, which might be expected to have a structural resemblance to $Ba_2Si_4O_{10}$, contains an entirely different type of polymer (*7*). It is formed by repetition of an $(SiO_3)_4^{-8}$ element, but one having a different configuration from that present in Fig. 4. The element and the structural pattern of the $(Si_4O_{10})_N^{-4N}$ polymer is similar to that of apophyllite.

In the end it seems that silicate polymers have a preference for four and six SiO_4 membered rings as polymer elements. Since this is general, it would appear in part to be determined by factors other than the surroundings in a specific solid and might be due to the considerable concentration of the pattern elements in the melt. It is not much better than a guess to point out that the more condensed polysilicates are formed

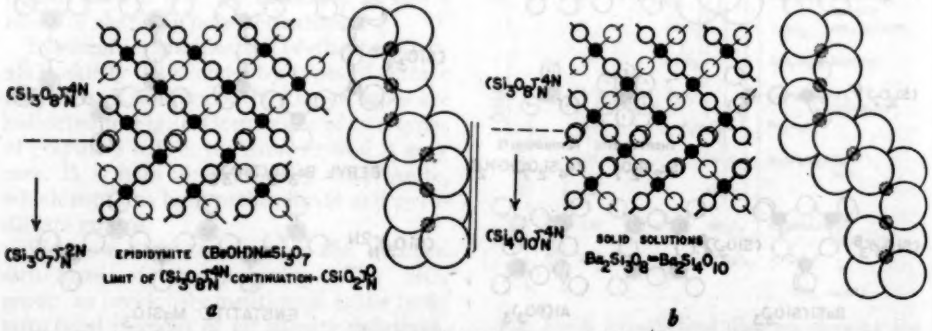

Fig. 4.—(*a*) The polymerization pattern of $(Si_2O_7)_N^{-2N}$ in which $(Si_2O_3)_N^{-4N}$ chains can be considered as the pattern element; (*b*) A diagram illustrating the probable way in which SiO_2 is added to the $(Si_2O_3)_N^{-4N}$ chains of $Ba_2Si_3O_8$ to give the sheet polymer $(Si_4O_{10})_N^{-4N}$ of $Ba_2Si_4O_{10}$.

through the intermediary of preformed metasilicate rings or ring fragments. The polymer pattern in a particular case is surely dependent upon the entire structure of the crystal, a factor that will not be considered here.

Let us now contrast the polymerization patterns of borates and silicates. Borate patterns are necessarily modified by the planar structure of the $(BO_3)^{-3}$ ion which is illustrated in Fig. 5. The B-O distance, 1.35A, is about 0.30A smaller than the Si-O distance and this changes the manner in which oxygen ions of neighboring groups pack sufficiently to modify extended patterns. This effect is well illustrated by the $(BO_2)_N^{-N}$ chain which is contrasted with the corresponding $(SiO_3)_N^{-2N}$ chain in Fig. 5.

Ortho-, pyro-, and tri-metaborate groups, shown in Fig. 5, are closely similar to the corresponding silicate groups. The hexametaborate ion $(BO_2)_6^{-6}$ would be expected to have the configuration of the polymer element of the hypothetical $(B_6O_{11})_N^{-4N}$ chain of Fig. 5. This should be contrasted with the corresponding $(SiO_3)_6^{-12}$ groups of Fig. 2. The $(BO_2)_4^{-4}$ ion shown in Fig. 5 might at first sight appear closely similar to a possible $(SiO_3)_4^{-8}$ metasilicate group, but it is particularly affected by repulsion of oxygen ions across the center of the group.

Polyborate polymers more condensed than the metaborate might be expected to make use of some of these ring metaborate groups as pattern elements. Thus the $(BO_2)_6^{-6}$ metaborate group could be condensed rather strictly after the pattern of the $(SiO_3)_6^{-12}$ group as shown in Fig. 3, giving rise to $(B_4O_7)_N^{-2N}$ and $(B_2O_3)_N^{-N}$ chains, and, in the limit, to $(B_2O_3)_N^0$ sheets. The first of these might be expected to appear in borax, the so-called sodium tetraborate decahydrate, and the last could be a modification of boric oxide. Intermediate members could be represented among the polyborates that are present in the Alkali Oxide–B_2O_3 systems.

The tetraborate group $(BO_2)_4^{-4}$ group illustrated in Fig. 5 could not be a simple pattern element as any linoleum designer could readily see. Thus whatever might be the nature of polyborates, they cannot make any great use of a four (BO_2) membered element of pattern in contrast to polysilicates in which the four membered element is commonly used.

While the structure of none of the polyborates is known, their properties can serve as a guide for further discussion. Many of the anhydrous ones form relatively quickly from melts, lack distinctive cleavages, and readily dissolve in water. These are definitely properties of limited groups rather than of sheet and chain polymers.

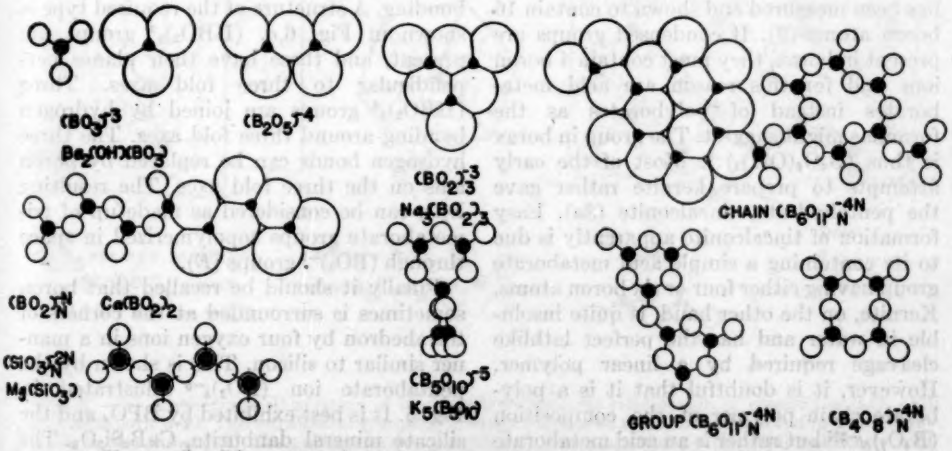

Fig. 5.—Possible pattern elements of some ortho-, pyro-, meta-, and poly-borates. These are to be compared with the silicate groups in Fig. 2.

What might be the structures of such polyborate groups, and why are they not exhibited by polysilicates?

The $(B_6O_{11})_N^{-4N}$ polymer which is represented by compounds such as $Cd_2B_6O_{11}$ and which, of all the polyborates, approaches most closely to the metaborate composition might be considered first. It could be an infinite chain as shown in Fig. 5. However, it could be more simply formed from two $(BO_2)_3^{-3}$ groups as also shown in this figure. Sharing of the other two oxygen ions of one $(BO_2)_3^{-3}$ group by $(BO_2)_3^{-3}$ groups would give a $(B_{12}O_{21})^{-6}$ group or more simply the tetraborate, $(B_4O_7)^{-2}$. It is seen that a structural element of these condensed groups is the tri-metaborate group, $(BO_2)_3^{-3}$. Addition of a third tri-metaborate group to the $(B_6O_{11})_N^{-4N}$ group shown in Fig. 5 to form a 6-B membered ring would give a group having the composition $(B_7O_{16})^{-3}$ or $(B_3O_5)^{-1}$. Other possibilities are shown in Table 1. The matter is not pressed further since it is easy to fall into artificiality and thus obscure the essentially correct features.

Most naturally occurring borates formed from aqueous solutions and are often hydrates (*8*). Their behavior is illustrated by the sodium salts borax, tincalconite and kernite, the first and last of which are the most important ores of boron. Borax and tincalconite are readily soluble in water. The monoclinic unit of structure of borax has been measured and shown to contain 16 boron atoms (*9*). If condensed groups are present in borax, they must contain 4 boron ions and for this reason are acid metaborates instead of polyborates as the formulas might suggest. The group in borax is thus $(B_4O_5(OH)_2)^{-2}$. Most of the early attempts to prepare kernite rather gave the pentahydrate, tincalconite (*8a*). Easy formation of tincalconite apparently is due to its containing a simple acid metaborate group having either four or six boron atoms. Kernite, on the other hand, is quite insoluble in water and has the perfect lathlike cleavage required by a linear polymer. However, it is doubtful that it is a polyborate chain polymer of the composition $(B_4O_7)_N^{-2N}$ but rather is an acid metaborate chain $(B_4O_5(OH)_2)_N^{-2N}$. (*D*)

The tendency for condensed borates in aqueous systems to be limited to the metaborate stage of polymerization is shown by the system H_2O–B_2O_3 in which metaboric acid is the most condensed polymer (*10*). Metaboric acid, as shown by Morey, Kracek, and Merwin, of the Geophysical Laboratory, exists in three forms the properties of which suggest that they contain group rather than chain polymers. One of these modifications holds an interesting key for us.

Boron trioxide is of particular interest in that it was one of the most difficult inorganic compounds to crystallize. Crystallization was first independently accomplished about seven years ago by McCulloch(*11*) and by Morey, Kracek, and Merwin (*10*). At first consideration it would appear that B_2O_3 would have to be a sheet type polymer since there is no very apparent way to obtain cross linking in space with $(BO_3)^{-3}$ as the simplest element.

Morey, Kracek, and Merwin showed that B_2O_3 crystallizes only in the presence of the most stable form of metaboric acid. This form is cubic and the unit of structure contains 24, HBO_2 (*10*). From these few facts alone it is possible to obtain the essential details of the HBO_2-I structure and some suggestions about the polymerization pattern of B_2O_3. The metaborate groups in HBO_2-I must contain 3, 4, or 6 boron atoms and must be associated through hydrogen bonding. A structure of the required type is shown in Fig. 6,*a*. $(HBO_2)_3^0$ groups are present, and these have their planes perpendicular to three fold axes. Three $(HBO_2)_3^0$ groups are joined by hydrogen bonding around three fold axes. The three hydrogen bonds can be replaced by boron ions on the three fold axes. The resulting B_2O_3 can be considered as made up of trimetaborate groups copolymerized in space through $(BO_3)^{-3}$ groups (*E*).

Finally it should be recalled that boron sometimes is surrounded at the corners of tetrahedron by four oxygen ions in a manner similar to silicon. This is shown by the pentaborate ion $(BO_3)_5^{-5}$ illustrated in Fig. 5. It is best exhibited by BPO_4 and the silicate mineral danburite, $CaB_2Si_2O_8$. The former has a structure similar to the high

temperature cristobalite modification of SiO_2 and the latter is also a space type polymer.

We now turn briefly to consider the polymer chemistry of sulphates and phosphates. The first holds little of interest since it is restricted to the neutral metastage, which, however, is represented both by group and linear polymers of SO_3. Phosphates might be expected to parallel silicates closely in their ways of condensation. They fail in this respect for several reasons, chief among which is the different requirement of the electrostatic valence principle due to the increased charge of phosphorus and the increased tendency to form covalent bonds (*F*). For these reasons polyphosphates are not expected to form from aqueous systems at low temperatures without some source of energy, silica can crystallize as quartz in the presence of water with which P_2O_5 reacts violently.

Phosphorus pentoxide is equivalent to $(Si_2O_5)_N^{-2N}$, which was found to polymerize in sheets according to three different patterns. If $(P_2O_5)_N^0$ and $(V_2O_5)_N^0$ are considered they are found to represent group, sheet, and space polymers. (*12*) These are illustrated in Fig. 6,*b*. A main structural principle in these polymers is the necessity for the unshared oxygen ion to approach a P or V ion to satisfy the electrostatic valence principle. This requirement operates to destroy possible highly symmetrical polymer patterns similar to these discussed for polysilicates.

Very little structural information is available on polyphosphates, and this is equally true for equilibrium data. In fact, the only binary system on which reasonably complete data are available is the system CaO-P_2O_5 on which Mr. Hill and Mr. Reynolds of the Fertilizer Division and Dr. Faust formerly of that Division have been working (*13*). Some of the compounds observed are shown in Table 3. The polyphosphates $Ca_2P_6O_{17}$ and CaP_4O_{11} might be expected to have structures similar to the hypothetical $(B_6O_{11})_N^{-4N}$ chain polymer and the $(Si_4O_{11})_N^{-6N}$ chain polymer of the amphiboles. The very little information available on the crystals, chiefly absence of lathlike cleavages, however, indicates a group polymerization.

Polyphosphate group polymers could, as a matter of fact, follow analogous patterns to some of the polyborate group polymers previously discussed. Thus $(P_6O_{17})^{-4}$ could be formed by sharing of one oxygen ion between two $(PO_3)_3^{-3}$ trimetaphosphate groups equivalent to the $(B_6O_{11})^{-4}$ group polymer of Fig. 5, and the $(P_4O_{11})_N^{-2N}$ group poly-

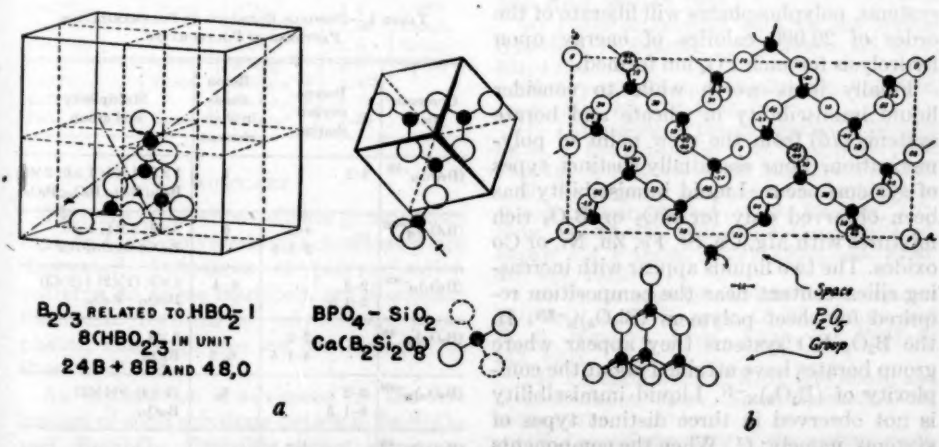

Fig. 6.—(*a*) A schematic illustration of the possible structural relationship of crystalline B_2O_3 and cubic metaboric acid. The tetrahedral grouping of oxygen ions around boron as observed in a few compounds is also shown; (*b*) The polymerization patterns of the orthorhomic and cubic modifications of P_2O_5. Distances in A units from the plane of the projection are indicated on the drawing.

mer could be formed from four $(PO_3)_3^{-3}$ groups. However, these group polymers can also be obtained in another manner which was not possible for polyborates. This would make use of the $(PO)_4^{-4}$ element, $(P_6O_{17})^{-4}$ combining two of these elements and $(P_4O_{11})_N^{-2N}$ three of them.

Phosphates exhibit one property to an apparently greater extent than do silicates, namely the formation of compounds intermediate between the pyro- and meta-degree of polymerization. These must be open or branch chains, and the best example is afforded by the silicate zunyite which Pauling found to contain $Si_5O_{16}^{-12}$ groups. The central SiO_4 group shares each of its oxygen ions with neighboring groups. An analogous compound is probably present in the CaO–P_2O_5 system, the formula being $(P_6O_{16})^{-7}$. The greatly decreased charge relative to $(Si_5O_{16})^{-12}$ apparently operates to stabilize the polymer in the crystal. Similarly the group $(P_3O_{10})^{-5}$ polymer is present in the Na_2O–P_2O_5 system (*14*).

These groups intermediate between pyro- and metaphosphates, the di- and tri- PO_4 group polymers, have immense biological importance for it is through their formation in conjugation with the purine bases that energy is stored or released in small steps in carbohydrate utilization (*15*). Thus while polysilicates will form from dilute aqueous systems, polyphosphates will liberate of the order of 20,000 calories of energy upon hydrolysis for each PO_4 ion formed.

Finally it is worth while to consider liquid immiscibility in silicate and borate systems (*16*) from the view point of polymerization. Four essentially distinct types of systems occur. Liquid immiscibility has been observed only for SiO_2 or B_2O_3 rich mixtures with Mg, Ca, Sr, Fe, Zn, Ni, or Co oxides. The two liquids appear with increasing silica content near the composition required for sheet polymers $(Si_2O_5)_N^{-2N}$. In the B_2O_3–RO systems they appear where group borates have attained about the complexity of $(B_3O_5)_N^{-N}$. Liquid immiscibility is not observed in three distinct types of systems, namely: (1) When the components copolymerize, e.g., SiO_2–B_2O_3, SiO_2–Al_2O_3; (2) where a compound of very high melting point can remove small groups from the melt, e.g., ZrO_2–SiO_2, SnO_2–B_2O_3; (3) where the liquidus temperature is sufficiently reduced to permit crystallization of sheet and other complex polymers, e.g., K_2O–SiO_2, Li_2O–B_2O_3.

Liquid immiscibility then in silicate systems appears to result from mutual insolubility of space and sheet polymers arising from their greatly different configurations (*G*). The space polymer, high cristobalite, however, crystallizes best from the liquid of lower silica content possibly due to a continuous supply of small groups to the nucleated points. Viscosity is correlated with the type of polymerization but probably is not determinative for crystallization as is so often implied; it is a symptom, not a disease.

The form of B_2O_3 in the limit of B_2O_3–RO melts is probably not similar to the crystalline B_2O_3 related to HBO_2(I), but rather is a more random spatial array. Two liquids appear upon increasing B_2O_3 contents of the systems when groups become sufficiently complicated to have serious entropy factors operating against their elaboration compared with their copolymerization. In other words it is easier for groups to combine with each other than to build up gradually in more and more complicated ways.

It would have been difficult to follow in

TABLE 1.—POSSIBLE ELEMENTS IN POLYMERIZATION PATTERNS OF POLYBORATES

Composition	Boron-oxygen sharing	Boron atoms in chain element	Multiplicity and group
$(B_3O_5)_N^{-2N}$	2-2	1	1×3; 1×4; 1×6; 2×3 B_3O_5; B_4O_5; B_6O_{11}; B_6O_{10}
$(B_4O_{11})_N^{-4N}$	4-2 2-1.5	6	2×3; 3×4; 4×6 B_6O_{11}; $B_{12}O_{21}$; $B_{12}O_{20}$
$(B_5O_7)_N^{-2N}$	2-2 2-1.5	6; 4	4×3; (1×2)+(2×3) $B_{12}O_{21}$ B_9O_{14}
$(B_6O_{10})_N^{-2N}$	2-2 4-1.5	6; 3	3×3 B_9O_{15}
$(B_6O_{11})_N^{-2N}$	2-2 6-1.5	6	(1×4)+(4×3) $B_{16}O_{24}$
$(B_{12}O_{20})_N^{-2N}$	2-2 8-1.5		
$(B_2O_4)_N$?	2-1.5		

TABLE 2.—POLYMERIZATION IN SOME POLYBORATE MINERALS

Compound	Mineral	Acid metaborate structural element	Probable value of N
$Na_2O \cdot 2B_2O_3 \cdot 10H_2O$	Borax	$(B_4O_5(OH)_4)_N^{-2N}$ Group	1
$Na_2O \cdot 2B_2O_3 \cdot 5H_2O$	Tincalconite	$(B_4O_5(OH)_4)_N^{-2N}$ Group	1 or 1.5
$Na_2O \cdot 2B_2O_3 \cdot 4H_2O$	Kernite	$(B_4O_5(OH)_4)_N^{-2N}$ Chain	
$(NH_4)_2O \cdot 5B_2O_3 \cdot 5H_2O$	Larderellite	$(B_4O_5(OH)_4)_N^{-N}$ Group	

such a short time the details of the many patterns, the fine points of the various arguments, and the unelaborated implications. Interest and incentive of those who played prominent parts in the development of this subject when it was hot have passed to other fields or have been subdued by pragmatism. Since the many unanswered questions have no immediate hope of attention it seemed best to attempt some synthesis of answers. The final truth of the matter, however, is that the unrequited labor of many workers will be required to clarify the chemistry of phosphates and borates.

TABLE 3.—POLYMERIZATION OF PHOSPHATES AND SULPHATES

Known compounds in $CaO-P_2O_5$ system	Possible polymer type	Group composition	Oxygen sharing	Compound
$Ca_3(PO_4)_2 \cdot CaO$	Group	$(PO_4)^{-3}$		
$Ca_3(PO_4)_2$		$(PO_4)^{-3}$	4.0	$CaSO_4$
$Ca_2(P_2O_7)$		$(P_2O_7)^{-4}$	3.50	CaS_2O_7
$Ca(PO_3)_2$		$(PO_3)_\infty^{-1}$	3.0	$(SO_3)_\infty$
		$(PO_3)_N^{-N}$	3.0	$(SO_3)_N$
$Ca_2(P_4O_{12})$	Chain	$(P_4O_{12})_N^{-4N}$	2.833	
$Ca(P_4O_{11})$		$(P_4O_{11})_N^{-2N}$	2.75	
P_2O_5	Space	$(P_2O_5)_M^0$	2.50	

SUMMARY

Patterns after which silicate groups combine to form polymerized polysilicates are illustrated. Influences of polymerization patterns on phase equilibria are discussed. Structural features of polyborates, phosphates, and sulphates are contrasted with those of silicates.

An explanation is advanced for the formation of solid solutions between $Ba_2Si_4O_{10}$ and $Ba_2Si_4O_{10}$. Probable types of group structures in some hydrous polyborates are indicated and a possible structural relationship of HBO_2-I and crystalline B_2O_3 is pointed out. An explanation is given for the observed liquid immiscibility in silicate and borate systems.

APPENDIX

A. References

Discussions and references to the original literature for the many structures upon which this work is based will be found in:

(*1*) W. L. BRAGG, *Atomic structure of minerals*, Ithaca, 1937.

(*2*) Zeit. Krist. "Strukturbericht," Leipzig, 1931 et seq.

Pertinent phase equilibrium diagrams are summarized by:

(*3*) F. P. HALL and H. INSLEY, *Compilation of phase rule diagrams of interest to the ceramist and silicate technologist*, Journ. Amer. Ceramic Soc. **16**: 459, 1933; **21**: 113, 1938.

Other references and the subjects concerned, not the titles of the papers, are:

(*4*) Possible structure of anauxite, S. B. HENDRICKS, Journ. Geol. **50**: 276, 1942.

(*5*) Crystal structure of epididymite, T. ITO, Zeit. Krist. **88**: 142, 1934.

(*6*) Phase equilibrium data for the system $BaO-SiO_2$, P. ESKOLA, Amer. Journ. Sci. (5)**4**: 331, 1922.

(*7*) Crystal structure of gillespite, A. PABST, Amer. Min. **28**: 372, 1943.

(*8*) Discussions of the mineralogy of borates by W. T. SCHALLER: (*a*) U. S. Geol. Surv. Prof. Pap. 158–I, 1929; (*b*) Amer. Min. **27**: 467, 1942.

(*9*) Space group determinations for hydrates of sodium tetraborate: (*a*) W. MINDER, Zeit. Krist. (A) **92**, 301, 1935; (*b*) J. GARRIDO, Anal. Españ. Fis. y Quim. **30**: 91, 1932; Zeit. Krist. **82**: 468, 1932.

(*10*) Phase equilibrium data for the system $H_2O-B_2O_3$, F. C. KRACEK, G. W. MOREY, and H. E. MERWIN, Amer. Journ. Sci. (5)**35-A**: 143, 1938.

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(*14*) Phase equilibrium data for the system Na_2O-P_2O_5, E. P. PARTRIDGE, V. HICKS, and G. W. SMITH, Journ. Amer. Chem. Soc. **63**: 454, 1941.

(*15*) References to biological formation of di- and tri- phosphates, K. LOHMANN, Ann. Rev. Biochem. **27**: 125, 1938.

(*16*) Liquid immiscibility in silicate and borate melts: (*a*) J. W. GREIG, Amer. Journ. Sci. (5)**13**: 1, 133, 1927; (*b*) W. GUERTLER, Zeit. Anorg. Chem. **40**: 225, 1904.

(*B*). *Solid Solutions: Rapidity of Polymorphic Transitions*

Formation of solid solutions between compounds having the same degree of group polymerization is common among silicates and is an important factor in mineralogy. Mg_2SiO_4 and Fe_2SiO_4, for instance, form a complete series of solid solutions (the forsterite-fayalite series) and $MgSiO_3$ forms limited solid solutions with $FeSiO_3$, but the metasilicate and orthosilicates are mutually insoluble (N. L. BOWEN and J. F. SCHAIRER, Amer. Journ. Sci. (5)**29**: 151, 1935.) Solid solutions of this type are thought to be limited by the relative sizes of the varying ions (Mg^{+2} and Fe^{+2}) and by possible appearance of new phases due to the changing temperature of the liquidus.

Solid solutions reported to occur about $CaSiO_3$ in the system CaO-SiO_2 and between alkali silicates having different degrees of polymerization have not been found upon further work.

Excellent examples of the varying rates of polymorphic transitions dependent upon the degree of polymerization are afforded by the system $NaPO_3$-$Na_4P_2O_7$ (E. P. PARTRIDGE, V. HICKS, and G. W. SMITH, Journ. Amer. Chem. Soc. **63**: 454, 1941. Four rapid transitions were observed between five crystalline forms of the simple group pyrophosphate. Transitions between the three forms of the metaphosphate, which probably vary in their polymer patterns, were all sufficiently slow to allow ready quenching.

Transitions taking place without change in polymerization might be slow since the restraints of the solid need not readily permit rearrangement of groups in the absence of a liquid phase.

(*C*). *Structural Considerations for Solid Solutions between $Ba_2Si_3O_8$ and $Ba_2Si_4O_{10}$*

The mineral sanbornite has been described by A. F. ROGERS (Amer. Min. **17**: 161, 1932). It is possibly triclinic and closely approximates $Ba_2Si_4O_{10}$ in composition. The one perfect cleavage gives it micaceous characteristics. Eskola (*6*) gave the following properties for $Ba_2Si_3O_8$ and $Ba_2Si_4O_{10}$ prepared from melts:

$Ba_2Si_3O_8$	$Ba_2Si_4O_{10}$
$N_D\alpha = 1.597$	$N_D\alpha = 1.620$
$\beta = 1.612$	$\beta = 1.625$
$\gamma = 1.621$	$\gamma = 1.645$
Density = 3.73	Density = 3.93

The almost perfect cleavage is parallel to the plane $\alpha\beta$. Two other poorly developed pinacoidal cleavages are present in $Ba_2Si_3O_8$ crystals. Pabst (*7*) noted that the X-ray powder diffraction pattern of natural sanbornite is unrelated to that of gillespite, $BaFeSi_4O_{10}$, which is somewhat similar to apophyllite in its polymerization pattern (7).

The molecular volume of $Ba_2Si_4O_{10}$ is only about 9 percent greater than that of $Ba_2Si_3O_8$ which would correspond to an average increase of 2 percent in lattice dimensions. This is a very small change and shows that SiO_2 added to $Ba_2Si_3O_8$ goes into an essentially vacant position. Calculated and observed molecular refractivities are in agreement as required;

Compound	Molecular Refractivity	
	Observed	*Calculated*
$Ba_2Si_3O_8$	44.1	43.2
$Ba_2Si_4O_{10}$	50.9	51.5

Observed values were obtained from the average refractive index and calculated values by use of the following ionic refractivities $Ba^{++} = 5.30$, $O^{--} = 3.85$, and $Si^{+4} = 0.60$.

The suggested structure is in harmony with the above observations. It can most readily be checked by determining the lattice periodicities in the cleavage plane, one of which should be that required by an $(Si_3O_8)_N^{-4N}$ chain pattern element.

(*D*). *Structural Information on Hydrates of Sodium Tetraborate*

Borax.—$Na_2B_4O_7 \cdot 10H_2O$, monoclinic holohedral space group $C_{2h}^6 - C2/c$ (*9*).

Unit of structure, contains $4[Na_2B_4O_7 \cdot 10H_2O]$

$a = 11.82A$	$c = 12.30A$
$b = 10.61A$	$\beta = 106°35'$

Perfect cleavage parallel to (100), poor parallel to (110), and (010). Quickly dissolves to limit of solubility. Loses approximately $1H_2O$ between 150° and 500°C.

These observations require the presence of $[B_4O_5(OH)_2]^{-2}$ groups with the minimum symmetry of $C_i - \bar{1}$.

Tincalconite.—$Na_2B_4O_7 \cdot 5H_2O$, rhombohedral space group $C_{3i}^2 - R\bar{3}$ (*9*).

Unit of structure, contains $3[Na_2B_4O_7 \cdot 5H_2O]$

$a = 9.56$	$\alpha = 71°42'$

No pronounced cleavage. Quickly dissolves to limit of solubility.

Loses 16 percent of total water above 200° (*8a*).

These observations require the presence of $(B_4O_6(OH)_2)^{-2}$ or $(B_4O_5(OH)_3)^{-3}$ groups. Since

the compound can apparently form by dehydration of borax without the appearance of a liquid phase the $(B_4O_6(OH)_2)^{-2}$ group is probably present.

Kernite.—$Na_2B_4O_7 \cdot 4H_2O$, monoclinic holohedral.

Space group $C_{2h}^4 - P2/c$ (9)

Unit of structure contains $4[Na_2B_4O_7 \cdot 4H_2O]$

$a = 15.65$	$c = 7.01A$
$b = 9.07$	$\beta = 108°52'$

Perfect cleavages parallel to (100) and (001) and other less developed cleavages parallel to the b axis (*8a*). Very slowly attacked by water. Loses approximately $1H_2O$ above 200°C. (*8a*).

These observations require the presence of chain polymers parallel to the b axis. The polymers are probably metaborates having the composition $(B_4O_6(OH)_2)_N^{-2N}$. The b periodicity (9.07A) is 5 percent greater than the c periodicity of the orthorhombic $Ca(BO_2)_2$, 8.56A, which is the distance required in that compound for 4 elements of the metaborate chain. (W. H. ZACHRIASEN, G. E. ZIEGLER, Zeit. Krist. **83**: 354, 1932.)

(*E*). *Structural Information on HBO_2-I and B_2O_3*

Metaboric acid, HBO_2-I, was observed by Kracek, Morey, and Merwin (*10*) (KMM) to crystallize as rhombic dodecahedra with $n_D = 1.619$ and density = 2.486. Zachariasen (*10*) found that the cubic unit of structure has $a = 8.88A$ and contains 24, HBO_2. B_2O_3 crystals have been formed only in the presence of $(HBO_2)_I$ and KMM noted marked parallelism between edges and possibly faces of the two growing together. "Crushing either induces a minute lamellar twinning, or possibly reveals a twinning caused by an *inversion*" (*10*).

X-ray powder diffraction patterns of crystalline B_2O_3 can be indexed on a hexagonal lattice having $a = 4.33A$ and $c = 8.392A$ (Mr. H. F. McMurdie, personal communication). If the density is 2.53 (measured value 2.460 (10)) this unit contains 3, B_2O_3. Refractive indices are ω (or β and γ) = 1.648 and ϵ(or α) = 1.615, the mean refractive index being 1.634 which is somewhat greater than that of HBO_2(I).

(*F*). *Valence Factors Involved in Polymerization of Silicates, Borates, and Phosphates*

A thorough discussion of electronic configurations in these groups is given by Linus Pauling in the *Nature of the chemical bond*, Ithaca, 1939. Specific references are: *Borates*, pp. 196–197, 219; *Sulphates, silicates, phosphates*, pp. 221–231, 375.

An adequate summary, stated by Pauling is: "Although the metasilicates, disilicates, and other silicates in which tetrahedron corners are shared are very stable, the corresponding compounds of phosphorus and sulfur are unstable. The explanation of this is the following: an oxygen ion shared by two silicon tetrahedra satisfies the electrostatic valence rule, whereas there is an infraction by 1/2 for the common corner of two phosphorus tetrahedra and by 1 for two sulfur tetrahedra. In consequence the pyrophosphates and metaphosphates are unstable—they do not occur at all as minerals and in solution they hydrolyze easily to orthophosphates—and the pyrosulfates are exceedingly unstable. It is for the same reason that silicon dioxide is stable but phosphorus pentoxide and sulfur trioxide combine with water with great avidity."

Oxygen ions shared by borate groups satisfy the electrostatic valence principle, and for this reason polyborates might be expected to have as great stability as polysilicates in aqueous systems. Contribution of double bond configurations to the borate structure, however, operate against equal sharing of all oxygen atoms as required for some of the elements of polyborates. Since half of the oxygen ions are unshared in metaborates these compounds would be expected to have the hydrolytic stability of polysilicates.

(*G*). *Information on Liquid Immiscibility in Binary Silicate and Borate Systems*

Liquid immiscibility in silicate systems has been studied by J. W. GREIG (*16a*), and his publications should be consulted for additional information. Compositions at the lower limit of immiscibility and the temperature above which two liquids appear in a number of systems are indicated in the following table:

System	Temperature	Mole per cent SiO_2 at lower limit	Reference
MnO-SiO_2	1640°C	0.66	WHITE, HOWAT, HAY, and ROY, Journ. Roy. Tech. Coll. Glasgow **3**: 239, 1933–36.
CaO-SiO_2	1698	0.71	GREIG, *loc. cit.* (10)
MgO-SiO_2	1695	0.60	*Ibid.*
SrO-SiO_2	1693	0.80	*Ibid.*
FeO-SiO_2	1695	0.61	BOWEN and SCHAIRER, Amer. Journ. Sci. (5) **24**: 177, 1932.
ZnO-SiO_2	1695	0.66	BUNTING, Bur. Stand. Journ. Res. **4**: 131, 1930.
CaO-B_2O_3	960	0.72	CARLSON, Bur. Stand. Journ. Res. **9**: 825, 1932.
Mole per cent of SiO_2 required for			
RSi_2O_5		0.667	
$R_2Si_2O_{11}$		0.578	
Mole per cent of B_2O_3 required for			
$Ca_2B_{14}O_{17}$		0.724	
CaB_2O_{13}		0.750	

ETHNOLOGY.—*"Tapirage," a biological discovery of South American Indians.*[1] ALFRED MÉTRAUX, Bureau of American Ethnology.

A striking feature of the Indian cultures of South America is the extensive use of feathers both for body ornaments and for decorations on weapons and other artifacts. Nowhere have feathers been worked more lavishly or with greater skill than there. Among the first treasures wrested from Brazil were the brilliant feather cloaks worn by Tupinamba chiefs. Today the National Museum of Copenhagen exhibits these masterpieces of the *ars plumaria*, as it has been called, among its most prized jewels.

The birds of the Tropics provided the most splendid materials for these fragile fabrics. The various representatives of the parrot family, with their bright wings and many with long tails, were in special demand, and large numbers of them were kept in every Indian village or encampment, both as pets and as reserve supply of feathers for new headdresses or arm bands. Despite the variety of feathers already at their disposal many Indian tribes found means of improving on nature.

Two chroniclers of the sixteenth century, Soares de Souza (1) and Magalhães de Gandavo (2), reported that the ancient Tupinamba Indians of the Brazilian coast knew how to change the color of the feathers on living birds. They took young common parrots, plucked their feathers, and smeared the bald spots with frog blood to which "certain other substances were added." The new feathers grew in yellow. The Portuguese immediately assumed that the Indians altered the plumage of common birds in order to cheat the White traders who might mistake them for specimens of some rare species.

That this technique was known to South American Indians long before Columbus may be surmised from its wide distribution throughout the continent. The Indian process was so familiar to the French colonists of the Guiana that they had a noun, *tapirage*, to designate the operation and a verb, *tapirer*, to express the action of changing the color of a bird's plumage. In Brazil, parrots that have been subjected to the process are called "contrafeitos."

Father Juan Rivero (3) has a good description of tapirage as it was practiced among the Achagua Indians of the Upper Meta River. "The Indians," he writes, "know how to make their parrots grow feathers of various colors, in order to increase their value, either for trade purposes or for their own use in their feasts. They obtain this result in the following way: They catch a live toad which they prick repeatedly with a thorn until the blood oozes. Then they place the animal in a pot and sprinkle its wounds with ground red pepper. The toad, enraged by the treatment, slowly exudes its active humors mingled with the poison and the blood. To this they add a certain red powder called 'chica' (*Bixa orellana*), and by blending these ingredients they make a pigment. They pluck the feathers of a parrot and smear it with this ointment which they insert with a stick into the holes left in the bird's skin. The parrot suffers and for several days remains sad as a sick chicken. Sometime later, the parrot's feathers grow again so splendid and so beautiful that everyone admires the beauty and elegance of the new plumage. Red spots stand out with remarkable variety on a yellow background among green feathers." The Guayupe and Sae were also experienced in the art of changing the color of the feathers by rubbing the birds with a "paste and poison."

Humboldt (4) makes only a bare reference to the process but gives us the name of the frog used in preparing the ointment. The latter is the *Rana tinctoria* or a closely related species. The naturalist Wallace has an interesting statement on this subject. "The Indians," he says, "pluck the birds which they wish to paint, and in the fresh wound inoculate the milky secretion from the skin of a small frog or toad. When the feathers grow again they are of brilliant yellow or orange color, without any mixture of blue or green, as in the natural state of the bird; and on the new plumage being again plucked out, it is said always to come of the same color, without any fresh operation. The feathers are renewed but slowly, and it requires a great number of them to make a coronet."

[1] Received April 20, 1944.

Tapirage is still practiced by the Indians of the Rio Negro and Uaupes areas. Koch-Grünberg (6) noticed that the Indians of the Aiary River region "pull from the tame red macaws the green feathers at the base of the wings and smear the wounds with the fat of the pirarara fish or of a certain toad. The new feathers become beautifully orange-yellow and retain this color, even if several times changed, as they are pulled out from time to time, for purpose of dance decorations."

The French naturalist La Condamine (7) mentions the process of tapirage and states that it was practiced by the Indians of the Oyapock River. This scientist expresses some doubts as to the virtues of the frog blood and believes that the change in the color of the feathers is the result of the use of some acrid substance or of some natural accident which may occur every time a living bird is plucked without the addition of any particular substance. In French Guiana tapirage was a specialty of the Carib tribes, of the Galibi, in particular, through whom the colonists learn about it.

South of the Amazon, tapirage occurs sporadically. It is reported for the eighteenth-century Mojo. "They pluck the tail and wing feathers of the blue parrots and in the wounds put the exudations of a toad and they stop them with wax to keep the liquid inside. Thus they cause the new feathers to grow reddish, a color that they never lose" (8). In the collections of the Göteborg Museum in Sweden there is a headdress of the Huanyam, an Indian tribe of the same region, which contains "tapiré" feathers.

The Mundurucu (9) of the Tapajoz River smeared the plucked parrots with frog blood, the Bororo (10) of the Matto Grosso with the "sap of a certain tree." The process was so common among the Paressi Indians that it is mentioned in the eighteenth century by Pires de Campos (11) in his short account of this tribe.

The southernmost limit of tapirage is the Gran Chaco, where it has been described in great detail by Father José Sánchez Labrador (12). "The color which most appeals to the Mbayá men and women is yellow. But there are not sufficient birds in the country with feathers to satisfy their needs. Despite their simple minds, they have discovered the art of turning yellow the natural color of the plumes. They pluck them at certain times to get the colors which suit their taste. They pluck on a living parrot all the green feathers which they want to grow yellow, removing the large feathers, the down and the small barbs found under the feathers. On the bare surface they apply a pigment extracted from the roots of the logoguigo plant or of the *nibadenigo* tree (rucu, *Bixa orellana*). Both produce a saffron color. They rub these pigments with their fingers against the skin as if they wanted the blood to ooze. Only then do they put an end to the bird's martyrdom. When the new feathers grow, they look to see whether they are yellow or green. Generally they are of the former color, but if they see green ones among the yellow ones, they remove them and repeat the operation on the same spot. We never observed that they applied this procedure to any birds but parrots or that they used other pigments than the ones mentioned. Once the feathers have been plucked, the new ones are always yellow and never green."

Tapirage was also known to the Mocoví, who were closely related to the Mbayá (13). Very likely both tribes learned the process from the Arawakan Guana, who had migrated from the Amazonian Basin.

Today tapirage is still widely practiced by the mestizos of the States of São Paulo and Pará. They subject to the operation not only parrots but also birds of other species.

The German anthropologist Karl von den Steinen (14) supposes that tapirage was accidentally discovered by some Indian who rubbed a parrot with a medicinal substance after having plucked its feathers. The ornithologist Marshall (15) expresses some doubts as to the effects of the ointment on the change of colors, and he supposes that the transformation is the result of a special diet to which the plucked bird is subjected. He mentions the fact that goldfinches that have been fed oily seeds, such as colza or hemp, turn dark, and that canaries fed on Cayenne pepper become orange.

The Indians were aware of the effects of certain foods on birds' plumage and also seem to have used this method. Im Thurn (16) writes that the Macushi pulled out the feathers of birds, and smeared the wounds with rucu but that they also made the bird

drink "water in which more foroah (rucu) has been steeped, after which it is left for some months at the end of which time new yellow feathers have grown in the place of the abstracted ones." For the same purpose the Puinave give their parrots grease of the cajaro fish, a fish common in the Guaviare River (17). The plumage of a parrot put on such a diet first gets yellow spots and finally turns entirely yellow.

Father Constant Tastevin, a French missionary in the Upper Amazon region, sent me the following communication: "The Caboclos—the civilized Indians of the Solimoes—the Cocama, Cambeua, and others, feed their parrots the grease of the pirarara, a big fish called after the ara because of the red and yellow scales of its tail. Its grease has a lively yellow color and birds which eat it get a spotted red and yellow plumage which is considered very beautiful. The Caboclos change the color of their pet birds only to improve their appearance, not to increase their commercial value. People do not eat pirarara fish for several reasons—first, because it feeds on corpses, and, secondly, because it causes an unbearable itching to those who are afflicted with the skin disease called titinga or purupuru. This unpleasant disease is also ascribed to the consumption of this fish."

Koch-Grünberg found the same interpretation for the origin of the skin disease purupuru among the Indians of the Aiary region, and it is probable that these natives have also observed the effects of a diet of pirarara grease on the birds.

Do these facts indicate that in the change of color the diet alone is important or is it possible that the diet and the smearing of the plucked spots are equally effective, independently of each other?

The distinguished ornithologist Dr. Alexander Wetmore, of the Smithsonian Institution, kindly informed me that our data on tapirage are essentially correct and that the methods used by the Indians to change the color of the plumes were all equally efficient. In the case of frogs, it was not the blood, but the acrid secretion of the glands that provoked the change in color. When rucu is rubbed in the wounds left by the plucked feathers, the tissues absorb certain pigments that modify the color of the feathers. The influence of certain foods on the birds' plumage is well known; not only do canaries turn orange after eating red pepper, but in the zoos flamingos and scarlet ibises are fed crushed shrimps so as to keep their pink or red color, which they might otherwise lose. The color change occurs whenever the tissues absorb the pigment, irrespective of the method of application (19).

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LINGUISTICS.—*The origin of our State names.*[1] JOHN P. HARRINGTON, Bureau of American Ethnology.

The correspondence of the Bureau of American Ethnology has indicated for many years past that there is a widespread popular interest in the names of the States and Territories that compose the United States of America and that there has been constant demand for the probing into the origin and provenience of these names. During a period of years I have been collecting or assemblying truly vast materials on the subject of State and Territory names, and I early discovered that such collecting had never been done before by a person with a linguistic background and with government facilities. The names were found to dip deeply into both ethnology and history and many of them to be American Indian in origin.

Since the publication of all this material would be too bulky and expensive at the present time, the publishing of a preliminary, curtailed version is alone practical. The unraveling of a few of the names has been on the verge of the impossible, but every case nevertheless was attended with some success. Only in the instance of the name Oregon are further investigations still planned and in progress; the word is patently the same as the word hurricane, field work among French speakers in Canada having convinced me of this.

The two names Carolina and Dakota appear as State names only as oppositionally modified into pairs by the preplacing of North and South. New Hampshire, New Jersey, New Mexico, and New York have the preplacement of New, the first two by dint of contrast with British place names, the last two because of basin on Dutch and Spanish predecessor names. West Virginia alone has the setting of West. Rhode Island has the setting after it of Island, Virgin Islands of Islands. The two names Arkansas and Kansas are of one and the same origin, though derived through different channels. The District of Columbia is not termed a State. Only Alaska and Hawaii are still Territories. The Canal Zone, Puerto Rico, and the Virgin Islands are designated as Possessions.

ALABAMA. In origin the Muskhogean tribe name Alibamu. For a tribe name becoming used as a State name compare Arkansas, Dakota, Kansas, etc.

ALASKA. In origin the Aleutian name of the Alaska Peninsula.

ARIZONA. Papago Indian language for springlet.

ARKANSAS. In origin the name of a tribe or division, another form of the name Kansas.

CALIFORNIA. The early Spanish novel *Amadis de Gaula* consisted of four "books" written originally in Portuguese, probably by an author named Lobeira. These were translated into Spanish by Montalvo, who later independently wrote a fifth book entitled *Las Sergas de Esplandian*, first printed about 1511. The whole novel enjoyed unusually wide reading. In the fifth book is the first occurrence of the word California, as the name of an imaginary island, the queen for which was Calafia, and which island was infested with griffins. The entire setting of the section is the region of Constantinople, which was a city nearly as famous as Rome during the Middle Ages and with which city the caliphate was connected in every mind. Montalvo was undoubtedly thinking of the caliphate when he wrote California, and like a handwriting flourish at the end of the word his mention of the griffins led him to imitate Greek órnis, bird, or Latin ornaare, to adorn, wedged in as a third syllable, since to call the island Calafia would have made the name of the island and its queen identical. Montalvo claimed that he got the entire story from a Greek. Or Montalvo may actually have seen the famous old French Song of Roland, dating from about the year 1000, which has as its line 2924 "Califerne" used of the caliphate —even with the -r- of Montalvo's "California." Modern Spanish orthography happens to have also Esplandian, without any accent on the vowel of the last syllable, thus coinciding in this word with the orthography of 400 years ago.

[1] Received February 15, 1944.

CANAL ZONE. Latin canaalis, canal, may be a remnant of an old submerged bunch of words having the stem of Sanskrit khan-, to dig; or it may be connected with Latin canna, reed—Spanish caña, cañón surely come from Latin canna. The second word of the name is in origin Greek zóonee, a woman's girdle.

COLORADO. The river that empties into the Gulf of California very early became known in a variety of languages as the red river because of the chocolate color of its water. It has not generally been known that even in Latin colooraatus occurs meaning red, whence Spanish colorado, the ordinary and only vernacular word for red. Colorado was first applied as a description to the Little Colorado River, happening to agree with a description of the Colorado and of the Little Colorado which had since immemorial times been in vogue in several adjacent and near-lying American Indian languages.

CONNECTICUT. In origin native Algonquian for long river, referring, of course, to the Connecticut River.

DELAWARE. Named for Thomas West, Lord De La Warr (1577–1618), a British soldier and colonial governor of Virginia, De La Warr being an English barony dating from the 13th century. As a landname, La Warre appears as the name of an estate in Gloucestershire, England. Gloucestershire is the country of the upper part of the mouth of the Severn River. The original Baron De La Warr, however, was from Sussex.

DISTRICT OF COLUMBIA. The first word is from Latin districtus, masc., second declension, past-perfect participle of Latin distringere. The last word is from the artificial Latinized form, Columbus, of Colombo, surname of the Genoese who discovered America for the Spanish Kingdom. There is no proof whatever that Italian Colombo is connected with Latin columba, pigeon, Latin columbus, male pigeon. Latin forms country names in -ia, just as Greek does in -ía. One can actually find in old Spanish books the transitional spelling Colomb, which shows how Colombo was changed into modern Spanish Colón. The form Colombia is neither frying pan nor fire, but consists of taking Italian Colombo and changing its -o into -ia, while the straight artificial Latin form would be Columbia.

FLORIDA. Ponce de León on Easter Sunday, 1512, caught sight of Florida, and named it from the day, just as children were accustomed to being named. Easter is called in the Spanish calendar of the saints la pascua florida, the springtime (literally flowery) passover. English misaccents the word, throwing the second syllable accent to the first syllable.

GEORGIA. Named from King George I of England. The name is, of course, in honor of St. George, whose name is in origin the Greek word for farmer, literally earth-worker. Today, for instance, Russian uses a word for farmer meaning earth-worker.

HAWAII. Long have I labored in vain trying to get the analysis or original etymology of the name Hawaii, pronounced in the Hawaiian Polynesian language hawáy'i. Professor Judd, of the University of Hawaii, writes me that all we can say is that this is the ancient Hawaiian name of the island on which Honolulu is situated.

IDAHO. It was William Otogary who first informed me of the true origin of this name. Idaho was the name of the Salmon River Indians and one of the words best known to the early Whites. Adepts in the Shoshoni language state that this name means riverite, if there is such a word in English, or river-dweller, referring to the Salmon River.

ILLINOIS. This is a French formation from the native Algonquian word for man, warrior, with addition of the French -ois as in Iroq-ois.

INDIANA. Indiana was an early Indian refuge, much as Indian Territory was later an Indian refuge. Indiana is the Latin country name formation from Latin Indiaanus, better Indicus, a Hindoo. It was Columbus's own party that started applying the name India to the West Indies, thinking that the East Indies had been discovered. The name India is a Latin country formation in -ia derived from Latin Indus, the name of the great river of western India. This river is called in Sanskrit Sindhus, which is also applied to the region about the River Indus, and also the stream in general and even to the ocean. The word is imagined to be connected with the theme sidh-, and the river name therefore to mean something like goaler. In Greek, transmitted through Persian, and therefore with conversion of the s- into h- or nothing, the river name is Indós. Spanish indio, an Indian, is a corruption of indigo, and this for Latin Indicus. Greek has three forms for a Hindoo or Indian: 1, Indikós; 2, Indós; 3,

Indôoos; also a feminine Indís, a Hindoo woman. The Greek country name is Indía, but a corresponding form does not occur in Sanskrit.

IOWA. In origin a Siouan tribe name, apparently meaning putter to sleep.

KANSAS. The final -s is to be accounted for as French spelling of Kansa, Siouan tribe name. Arkansas is another version of this name.

KENTUCKY. Wyandotte Iroquoian for at the prairie.

LOUISIANA. Derivative of Louis, the earliest recorded spelling of which is Chlodowech. The Gothic of this name would have been *Hludaweiks, versal to *hludaweik, neuter, famous fight. There is evidence that the u of this name is short, hluda- and not hluuda-.

MAINE. The names Arcadie and Maine were both started by the very early French and applied to portions of what is now the State of Maine. Maine was a prominent province of older France, guessed to be the same as the second member of the Gallic tribe name from the time of Caesar which occupied the vicinity: Ceno-manni. Maine coast fishermen and others speak of the mainland as the main, but to connect this is a later popular etymology.

MARYLAND. Named for Queen Henrietta Maria, wife of King Charles I of England, who was daughter of King Henry IV of France. Mary is the Greek corruption of Hebrew Miryaam, and land is an old Germanic word for which Welsh and Polish cognates have been pointed out.

MASSACHUSETTS. Native Algonquian for flint hill.

MICHIGAN. Native Algonquian for large clearing.

MINNESOTA. From the name of a river. One can not do better than quote from Stephen R. Riggs's *Dakota-English Dictionary* (Contr. North Amer. Ethnol. 7: 316. 1890): "Mi'-ni-so-ta, *n. the Minnesota* or *Saint Peters River*. It means whitish water and is the name also of the lake called by the white people *Clear Lake*." The Dakota Sioux name of what is now called officially the Minnesota River first appears in Jonathan Carver's *Travels through the interior parts of North America* (London, 1778) in the form "Menesoter," and the accompanying map has "Minesoter." It was Gen. H. H. Sibley who, in 1848, first launched the spelling Minnesota, which in 1849 became officialized in the designation of Minnesota Territory, while at the same time the Sioux name for Rivière de Saint Pierre, St. Peters River, was restored to Minnesota River.

MISSISSIPPI. Native Algonquian for big river, a mere description.

MISSOURI. Neighboring Algonquian for big canoe haver, a name applied to a Siouan tribe.

MONTANA. The common Latin adjective for mountainous is montaanus, from Latin mons, masc., mountain. Judging from other State names, one would naturally take Montana to be feminine singular, but it can also be taken as neuter plural, for instance like English errata.

NEBRÀSKA. According to what Francis La Flesche told me, this name occurs in almost the same form in Omaha Siouan and in closely related languages and means flat water. According to La Flesche, this was the Omaha term concomitant to the French Rivière Platte; both were descriptive in origin.

NEVADA. This State is named from the famous Sierra Nevada, Spanish for snowy range, which used to be in view of the Spanish ships very early sailing along the upper California coast. Spanish nevado literally means besnowed, but is used as the adjective for snowy. It is connected with Spanish nieve, fem., snow.

NEW HAMPSHIRE. In the second member of this name we have a short-cut with whole middle syllable left out for Anglo-Saxon Haamtuunsciir, fem., literally the county of Haamtuun, which literally translated means village-ville. We fortunately have absolute proof in Old English that the syllable -tuun- simply got left out.

NEW JERSEY. Jersey, with corrupt j- for ch-, is what the popular pronunciation of centuries has turned Caesarea into. The Island of Jersey was a federal post, and termed in Latin (Insula) Caesarea. A more widely known Caesarea (Green loanword form Kaisáreia), literally federal-one, was a city in Palestine. The name is in origin the feminine of one of the adjectives derived from the name Caesar, which is related to Latin caesaries, fifth declension, hairiness.

NEW MEXICO. The second member is for Meshí'ko, Aztec place name. The vague northernmost province of Mexico was early termed Nuevo México in Spanish, and when the region was annexed to the United States, part of it

became the Territory, later the State, of New Mexico.

NEW YORK. After Professor Geary, excellent knower and speaker of Irish, has researched for years on the derivation of the word York, he still favors its meaning yew grove. I also have followed him, weighing all sources of information. York is actually recorded in Latinized form before the Anglo-Saxon invasion as Eboraacum. The form in ancient British, alias ancient Welsh, formerly spoken throughout England, must have been Eboraakon.

NORTH CAROLINA. Carolina is the feminine, referring to country, in this instance to a colony, first bestowed in honor of Charles IX of France, subsequently of Charles I and Charles II of England. The artificial Latinized form of the name Charles is Carolus; for the explanation of the insertion of a middle vowel in which one need only point to Dutch Karel, Charles, which also has an easing vowel. Karl is an old Germanic name, the Gothic form of the name would have been *Karls. A form identical with the name also appears as one of the several words meaning man in Old Icelandic. That karl means man also in the sense of a male as opposed to the sense of female, is brought out in Old Icelandic, in which we have karla-foolk, males. In modern Icelandic slang karl means old-man. The personal name Karl is presumed to have had the same origin as the noun of general meaning.

NORTH DAKOTA. The second member is a Siouan tribe name occurring in dialects with l- instead of d-, and said to mean originally friend; with this meaning compare the original meaning of Texas.

OHIO. Native Iroquoian meaning pretty, applied to the Alleghany Reservation, the Allegheny River, and to what is viewed as the down country extension of the Allegheny River: the Ohio River.

OKLAHOMA. A name started by the Rev. Wright, translating red person into Choctaw. The red man did not call himself red man in purely aboriginal times anywhere that I know.

OREGON. The name Oregon can be followed back to Rogers, who in 1765 wrote Ourigan. There is evidence, both as regards the life of Rogers and of his friend Carver and as regards the spelling used by Rogers, that the name is French Canadian in provenience, and field work in Canada and on the Pacific coast has convinced me of this. The word means in French Canadian squall or storm and is the same in ultimate origin as the English word hurricane.

PENNSYLVANIA. William Penn in his own handwriting makes several references to the naming of Pennsylvania. Although not a Welshman, and born in the English-speaking border of Wales, Penn wanted the colony called New Wales, but King Charles II of England, who had the granting of the charter and the naming of the colony in his power, devised, or had suggested to him, the name Sylvania, which is English woodland translated into Latin, and the King then prefixed the name Penn to this in honor of the King's old acquaintance, William Penn's father, Admiral William Penn. Sylva, or silva, is the Latin for forest, and Greek hýlee, wood, earlier sûlee, must be in some way connected with this, but records are inadequate for proving just how.

PUERTO RICO. This is Spanish for rich harbor. Spanish puerto is from Latin portus, masc., fourth declension, harbor, this being the same word as Norwegian fjord and English ford. Rico is Spanish for an earlier ricco; Italian still has ricco. This adjective is taken over from Germanic, where we find Gothic reiks being the adjective of Gothic reiks, chief, and evidently meaning chieftainly, regal, powerful, rich. Spanish still uses rico meaning fortunate, for example in the sentence: You are very fortunate in still have a father.

RHODE ISLAND. Although the very early Verranzano Relation compares Rhode Island in size with the Isle of Rhodes in the Mediterranean, the actual use of the name Rhode Island starts with the Dutch explorer Block, who calls Rhode Island in Dutch Roodt Eylandt, meaning red island, called from its red appearance; the writer remembers strikingly the red appearance of the neighboring Martha's Vineyard island when viewed from a boat.

SOUTH CAROLINA. The second member has been treated above.

SOUTH DAKOTA. The second member has been treated above.

TENNESSEE. A Cherokee village name, extended to become a river name and a region name, and finally a State name.

TEXAS. Caddo téysha, in earlier pronuncia-

tion táysha (just as Icelandic steinr, stone, is in the earlier Gothic stains), is used as a salutation meaning friend, and was widely known and used as a Caddo word and as a designation for Caddo and friendly Indians; compare the meaning of Dakota, which is said to have meant friend and was used as a regular tribe name.

UTAH. Named from Spanish Yuta, Ute Indian, and the Spanish from Athopascan Indian meaning higher.

VERMONT. Intended to be French for the Green Mountains, the correct standard French for which would be: les Montagnes Vertes.

VIRGIN ISLANDS. In origin a religious name. Latin virgoo, a virgin, has been ingeniously connected by Brugmann with Greek parthenós virgin, but perhaps an easier etymology is to connect it with Latin virga, sprout.

VIRGINIA. A colony name in artificial Latin in honor of Queen Elizabeth of England, who was fond of being known as the Virgin Queen.

WASHINGTON. Study of early spellings makes it absolutely certain that the name is Wassington, that the sh is a corruption, and that the Anglo-Saxon would have been Wassinga Tuun, the villa or stockade of the Wassings. There are two, and were formerly probably three, places in England by this name. Wassing is patently a patronymic derived from Wassa, an old weak-declension personal name not extant in Anglo-Saxon writings. The genitive of this would have been, of course, Wassan, but in Anglo-Saxon weak declension nouns were already taking -ing with loss of the -n-. Such an English adjective as Platonic, Plutonic, taken from Greek, retains the -n-, but Anglo-Saxon already formed Wass-ing from Wassa, with loss of the weak -n-. The meaning of the personal name Wassa is not known.

WEST VIRGINIA. The second member has been treated above.

WISCONSIN. In origin the native Algonquian name meaning grassy.

WYOMING. Native Delaware Algonquian for large prairie-place, corroborated by the Iroquoian equivalent being extant. Not an ancient name, but a descriptive one, given by Indians to the site of the present Wilkes-Barre, Pa.

BOTANY.—*A preliminary account of the plant diseases of El Salvador.*[1]

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In the development of a national agricultural research program for the Republic of El Salvador it was deemed needful to make a study of the diseases affecting the economic plants of the country. Mycologists and plant-disease students have visited the Republic, but no one has hitherto made detailed collections of disease material. A knowledge of the naturally occurring plant diseases of a country is considered one of the essentials of an agricultural research program, and it has been one of the junior author's problems to obtain this information in El Salvador. The collections here reported were all made in 1943 during the months of May, June, July, and the first half of August. The six months' wet season had just begun when this work was started.

El Salvador has an area of 13,176 square miles, somewhat less for example than that of Switzerland. It has a number of volcanoes, with one or more that are still quite active, and elevations where crops are grown vary from sea level on the coastal plain bordering the Pacific Ocean to around 9,000 feet. Its climate is affected by the cordillera that marks its boundaries with Guatemala and Honduras, and on its higher tablelands and mountain slopes where cultivation of crops is most intensive, it is almost temperate in character. In the lowlands along the Pacific and in the lower river valleys, such as that of the Río Lempa, the temperatures are typical of the deep tropics. It is a thickly populated country with a backbone of stable agriculture; large holdings maintained by wealthy landowners, a few moderate-sized farms handled by those of lesser means, and, most numerous, small plots that are worked on a subsistence basis

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by the shifting type of cultivation indigenous to the country. Certain crops have been grown in El Salvador since prehistoric times (e.g., maize, beans, squash), and others have been introduced within more recent times (e.g., sugarcane, coffee), while such plants as abacá and fiber roselle have been grown in the country but a few years.

Published accounts of the plant diseases of El Salvador have been comparatively few. Dr. David J. Guzmán (5) published in 1919 a work entitled *Fitopatologia, estudio de las enfermedades que afectan a las plantas agricolas de El Salvador*. It contains a general discussion of plant diseases and insect pests and their control, but very few concrete references to plant diseases occurring in El Salvador. Furthermore, a number of the diseases he recorded for the country are not present, for example, sugarcane smut. His reports have not been incorporated here.

Standley and Calderón (6) included in their *Lista preliminar de las plantas de El Salvador* fungi from the excellent collections of Standley, a number of which were economic forms and have been recorded here under the several hosts involved. Two of the rust fungi collected by Standley were named by Dr. J. C. Arthur (2) as new to science.

In more recent years studies of coffee diseases have been made at the Coffee Experiment Station at Santa Tecla and records of these published in reports by S. Calderón, J. A. Alvarado, and F. Choussy (1, 3, 4).

In the following account the material is presented on a host basis, and in alphabetical order of the technical names of the plants involved. Disease-producing fungi are also listed alphabetically under the hosts. Localities are given and the collector's numbers where available. The collector in all cases is the junior author unless otherwise specified. The specimens have been divided and a set deposited in the mycological collections of the Bureau of Plant Industry and a representative set has been taken by the junior author for deposit in El Salvador.

AGAVE spp. Sisal, henequen.

Colletotrichum agaves Cav. This anthracnose fungus produces oval leaf spots up to 1 cm in diameter with raised margins. On *Agave americana* L., Lake Ilopango Road, no. 300; on *A. fourcroydes* Lem., San Miguel, no. 240.

Diplodia theobromae (Pat.) Nowell causes a black rot of the leaves of *A. fourcroydes* Lem. (henequen), which brings about serious losses of fiber often reaching 25 percent of the crop in a given area. The fungus, which has been listed under a variety of names (*D. natalensis* P. Evans, *D. cacaoicola* P. Henn., etc.), attacks a wide range of tropical and subtropical economic plants causing fruit rot, twig and branch die-back, and leaf spots and rot. Noted particularly at San Miguel, nos. 239, 241, 243, 244, 414; La Libertad, no. 400. An earlier specimen from El Salvador on *A. sisalana* Perr., collector and exact locality unknown, is also in the herbarium of the Bureau of Plant Industry.

ALLIUM spp.

Alternaria porri (Ell.) Saw. Black mold and purplish lesions on leaves of *Allium cepa* L. (onion). La Ceiba, no. 19 and *Allium porrum* L. (leek), Cuscutlan, no. 310.

ALTHAEA ROSEA Cav. Hollyhock.

Virus. An undetermined virus characterized by yellow chlorotic leaf lesions mixed with light and dark green islands. La Ceiba, no. 22.

ANDIRA JAMAICENSIS (W. Wright) Urb.

Gloeosporium sp. Anthracnose on leaves Plaza, San Miguel, no. 215.

Polystigma pusillum Syd. Forming angular brown leaf spots. Previously known from Guatemala and the Dominican Republic. Under the name *Physalospora andirae* F. L. Stevens, the fungus has been collected in Puerto Rico, Virgin Islands, and Panama. San Miguel, no. 215; San Salvador, no. 309.

BAUHINIA spp.

Uromyces guatemalensis Vest. Rust on leaves of *B. ungulata* L. Tonacatepeque, Dept. San Salvador, Standley, no. 19471; Santa Ana, Dept. Santa Ana, Standley, no. 20357.

Uromyces jamaicensis Vest. Rust on leaves of *B. pauletia* Pers. San Vicente, Dept. San Vicente, Standley, no. 21286.

BETA VULGARIS L. var. CICLA L. Swiss Chard.

Cercospora beticola Sacc. A leaf spot produc-

ing fungus which is common throughout the range of the host. La Ceiba, no. 77; Cuscutlan, no. 313.

BOEHMERIA NIVEA (L.) Gaud. Ramie.

Virus. An undetermined virus was noted causing a severe stunting and mild leaf mottling of infected plants. Santa Tecla, no. 283.

BRASSICA OLERACEA L.

Alternaria brassicae (Berk.) Sacc. Black leaf spots on leaves of cabbage, La Ceiba Exp. Stat., no. 78; Volcano San Salvador, no. 350; on leaves of cauliflower (*B. oleracea* var. *botrytis* L.), La Ceiba Exp. Stat., no. 27.

BROMELIA KARATAS L.

Perisporium bromeliae F. L. Stevens. Black sooty patches on leaves. San Miguel, no. 245.

CAPSICUM FRUTESCENS L. Pepper.

Cercospora capsici Heald & Wolf. Leaf spot of common occurrence. La Ceiba Exp. Stat., no. 74; Cuscutlan, no. 316.

Cercospora diffusa Ell. & Ev. Diffuse, brown fungus patches on lower leaf surfaces. Cuscutlan, nos. 315, 316.

Virus. An undetermined virus with symptoms resembling those of common tobacco mosaic. La Ceiba, no. 75.

CARICA PAPAYA L. Papaya.

Oidium caricae Noack. This typical powdery mildew, in common with most other tropical forms of the family Erysiphaceae, does not produce the perfect or ascus stage. Originally described from Brazil but occurs sparingly in other papaya growing countries. La Ceiba Garden, no. 82.

Pucciniopsis caricae (Speg.) Earle. This fungus, producing small, circular, black, rustlike spots on papaya leaves, occurs wherever the host is grown and is economically important in producing premature death of infected leaves. It is also known as *Asperisporium caricae* (Speg.) Maub., and a perfect stage (*Mycosphaerella*) has been described, but not verified. La Ceiba, no. 82; Los Chorros, no. 301. The latter specimen is overgrown in part by an apparently undescribed white mold.

Virus. A definite virus disease characterized by severe malformation of older leaves and a stunting and mottling of young growth was noted at the La Ceiba Experiment Station, nos. 63, 64. The disease would appear to be similar if not identical with that reported for Jamaica and Puerto Rico.

CASSIA sp. Senna.

Rhizoctonia sp. A damping off of seedlings at La Ceiba, no. 330.

CENTROSEMA PUBESCENS Benth.

Uromyces neurocarpi Diet. Rust on leaves, Ahuachapán, Dept. de Ahuachapán, Standley, no. 19845.

CITRULLUS VULGARIS Schrad. Watermelon.

Pseudoperonospora cubensis (Berk. & Curt.) Rostew. Downy mildew. A common and often serious disease of this and other cucurbits. Shore of Lake Ilopango, no. 386; Valle San Juan, no. 430.

CITRUS AURANTIFOLIA (Christm.) Swingle. Lime.

Cephaleuros virescens Kunze. The algal leaf spot is common but never serious. Zapotitan, no. 365; Tejutla, no. 441.

Elsinoë fawcetti Bitanc. & Jenkins. The citrus scab fungus attacks the leaves and fruit, disfiguring the latter or even causing much premature dropping. Cuscutlan, nos. 318, 319.

Mycosphaerella sp. (?). A leaf spot characterized by brown, circular to irregular spots with much darker definite borders, showing on both surfaces of the leaves. The fungus is immature. Cuscutlan, no. 320.

COCOS NUCIFERA L. Coconut.

Diplodia cococarpa Sacc. Common on husks. Port of La Libertad, no. 399.

Exosporium palmivorum Sacc. Leaf spots on dead leaves. La Ceiba no. 393.

Leptosphaeria sp. On dead and dying leaf tips associated with the following.

Pestalotia (*Pestalozzia*) *palmarum* Cke. Associated with large, irregular, gray to deep brown leaf spots. La Cabana, no. 227; La Ceiba no. 292.

CODIAEUM VARIEGATUM (L.) Blume. Ornamental croton.

Gloeosporium sorauerianum Allesch. Anthracnose on leaves, marked by large, irregular, brown, diseased areas and often with premature defoliation. La Ceiba, no. 130.

COFFEA ARABICA L. Coffee.

Capnodium coffeae Pat. The sooty mold of coffee following the presence of aphids, mealybugs, or other insects is common in most coffee-growing areas. It is doubtless a mixture of several species, but for the most part conidial and pycnidial stages only are present. The name applied here is one of convenience only. Santa Tecla, nos. 101, 111; Santiago de Maria, S. Calderon, no. 2232.

Cercospora coffeicola Berk. & Cke. The brown eyespot is one of the common coffee leaf spots, but one which causes relatively little damage. Volcano San Salvador, nos. 11, 342; La Ceiba Exp. Station, no. 88; near Santa Ana no. 417. Also reported by Calderón (3) and Alvarado (1).

Colletotrichum coffeanum Noack. The anthracnose fungus produces large, irregular, brown blotches on leaves. Santa Tecla, no. 110. Probably merely another strain of *Glomerella cingulata* (Stonem.) Spauld. & Schrenk.

Heterodera marioni (Cornu) Goodey. The root-knot nematode was found producing heavy infections of roots of seedlings at Santa Tecla, no. 278. Determination verified by G. Steiner.

Micropeltis applanata Mont. Fly-speck fungus on leaves. Santa Tecla, S. Calderón, no. 2237.

Mycosphaerella coffeicola (Cke.). Leaf spot. Volcano Quetzaltepeque (San Salvador), no. 342; Santa Ana, S. Calderón, collector.

Omphalia flavida Maubl. & Rangel. The American leaf or eyespot disease, which is caused by this fungus, is widespread in the American tropics on coffee and various other economic woody plants and is doubtless widespread in El Salvador but is reported to date only from Santa Tecla from the collections of S. Calderón (3). In the past the fungus has been classified erroneously as *Stilbum flavidum* Cke. and *Stilbella flavida* (Cke.) Lindau.

Rhizoctonia sp. Coffee seedlings killed by a "damping off" fungus of the genus *Rhizoctonia*, and probably a strain of *R. solani* Kuehn, were noted at Santa Ana, no. 21, and at Santa Tecla, nos. 105, 106.

Nonparasitic leaf abnormalities. Several types of bronzing, chlorosis, and similar disturbances were noted on coffee leaves at Santa Tecla, due possibly to lack of shade, soil deficiencies, and other environmental or cultural difficulties.

CUCUMIS SATIVUS L. Cucumber.

Erysiphe cichoracearum DC. Powdery mildew occurs commonly on this host, but in the conidial (*Oidium*) stage only. La Ceiba Exp. Stat., no. 29.

Pseudoperonospora cubensis (Berk. & Curt.) Rostew. Downy mildew is a common disease on this host and often destructive. La Ceiba Exp. Stat. nos. 28, 72.

Virus. An undetermined virus disease was noted which was not typical of that due to *Marmor cucumeris* var. *vulgare* Holmes, but was characterized by the harsh, corrugated appearance of the leaves with vein clearing. La Ceiba Exp. Stat., no. 30.

CUCURBITA spp. Pumpkin, squash.

Cercospora cucurbitae Ell. & Ev. Leaf spot on C. *maxima* Duchesne. Zapotitan, no. 425; Valle de San Juan, no. 431.

Erysiphe cichoracearum DC. Powdery mildew in the *Oidium* stage is common on all types of *Cucurbita*. Shores of Lake Ilopango, no. 385; Volcano de San Salvador, no. 261; San Andres, no. 362. The fungus on the first specimen cited is overgrown by *Cicinnobolus cesatii* D By.

Virus. An undetermined virus disease of the *Marmor* type characterized by severe mottling of leaves and stunting of plants of *Cucurbita pepo* L. occurred near Sacocayo, no. 146; shores of Lake Ilopango, no. 389; near Aguafria, no. 427.

CYMBOPOGON NARDUS (L.) Rendle. Citronella grass.

Virus. A leaf mottling typical of *Marmor sacchari* Holmes, which occurred on sugarcane in adjoining fields, was noted at Santa Tecla, no. 275.

CYNODON DACTYLON (L.) Pers. Bermuda grass.

Helminthosporium giganteum Heald and Wolf. The fungus causes yellow or straw-colored spots with narrow brown borders on leaves. Previously reported from Texas. Cafetelera Station, Santa Tecla, no. 276.

Puccinia cynodontis Delacr. The rust on this host is a widespread fungus, often injurious. Zacatecoluca, no. 434.

DATURA STRAMONIUM L.

Alternaria crassa (Sacc.) Rands. On leaves. Los Planos, no. 4.

Virus. An undetermined virus causing chlorosis and stunting of infected plants was seen at Los Planos, no. 5.

DAUCUS CAROTA L. Carrot.

Alternaria carotae (Ell. & Langl.). Leaf blight occurred at La Ceiba, no. 33; Volcano San Salvador, no. 341.

DESMODIUM spp.

Alternaria sp. Associated with a leaf-spotting, on *Desmodium* sp. Santa Tecla, no. 281.

Cercospora desmodii Ell. & Kell. Leaf spot on *Desmodium* sp. La Cabana, no. 225.

Isariopsis caespitosa Petr. & Cif. Angular leaf spot on *Desmodium* sp. Near Herradura, no. 390; Lagarto, no. 428. Doubtfully distinct from *I. griseola* Sacc., occurring on *Phaseolus* and other legumes.

Parodiella perisporioides (Berk. & Curt.) Speg. On leaves of *Desmodium nicaraguense* Benth. & Oerst. Santa Tecla, no. 280.

Uromyces hedysari-paniculati (Schw.) Farl. Rust on leaves of *Desmodium barclayi* Benth., Ahuachapán, Dept. de Ahuachapán, Standley, no. 19846; *Desmodium nicaraguense* Benth. & Oerst., Santa Tecla, no. 280; *Desmodium scorpiurus* (Sw.) Desv., near San Salvador, Standley, nos. 19651, 22743.

Virus. An undetermined virus marked by mottling of leaves of *D. rensoni* Painter, Santa Tecla, no. 282.

EPIDENDRUM DIFFORME Jacq.

Uredo guacae Mayor. A rust disfiguring the leaves of *Epidendrum* spp. and related orchids in Central America and the West Indies. The record of its occurrence in El Salvador is based on a specimen found by Plant Quarantine inspectors on a plant offered for entry at San Francisco.

EUPHORBIA PULCHERRIMA (Klotzsch) Graham. Poinsettia.

Oidium sp. This appears to be the first report of a powdery mildew on this host. As is so commonly the case with tropical material, the perfect stage of the fungus is not present. It is possible that *Sphaerotheca euphorbiae* (Cast.) Salmon is the species involved. The fungus produces circular to irregular yellow to brown spots up to 1 cm in diameter, disfiguring the leaves and greatly lowering their ornamental value. La Ceiba, no. 96.

FICUS CARICA L. Fig.

Physopella fici (Cast.) Arth. The common fig rust brings about premature leaf fall. Finca Santa Ana, San Miguel, no. 210 (Uredo stage only).

FRAGARIA CHILOENSIS Duchesne. Strawberry.

Mycosphaerella fragariae (Tul.) Lindau. This fungus, producing a typical and at times damaging leaf spot, has followed the cultivated strawberry around the world. The conidial stage (*Ramularia tulasnei* Sacc.) was collected near the top of Volcano San Salvador, no. 351.

FURCRAEA sp.

Colletotrichum agaves Cav. Anthracnose on leaves. San Miguel, S. Calderón, collector, no. 2549; near San Jacinto, no. 2556.

Dothidella parryi (Farl.) Th. & Syd. On leaves, near San Salvador, S. Calderón, collector.

Trichocladium olivaceum Mass. On leaves. San Miguel, S. Calderón, collector, no. 2549.

GLIRICIDIA SEPIUM H. B. K. Madre de cacao.

Cyphella villosa Pers. ex Karst. Associated with a die-back condition of branches and twigs. Santa Tecla, no. 59a.

Fusarium decemcellulare Brick. Associated with cankers on stem and branches. Collected by S. Calderón, Santa Tecla.

Isariopsis sp. Causes definite, dark brown spots, 2–4 mm in diameter, fruiting on the lower surface. San Andres, no. 359.

Phomopsis sp. Associated with a die-back of twigs. Does not appear to differ from *Ph. gliricidiae* Syd., nor from *Ph. citri* Fawc., which latter form Wehmeyer considers the imperfect stage of *Diaporthe medusaea* Nitsch.

Rosellinia pepo Pat. Black root rot on rotting roots. Santa Tecla, collected by S. Calderón.

HIBISCUS sp. Fiber roselle.

Oidium sp. A powdery mildew on leaves which showed only the imperfect stage and hence was not further determinable, occurred at La Molina, Santa Ana, no. 305.

Vermicularia dematium Fr. Associated with cankered areas at base of plants. Santa Tecla, no. 122. Many plants at the Station have shown abnormal leaf fall and other abnormalities, but parasitic fungi do not appear to be involved and the trouble is more evidently the result of unfavorable environment. Various secondary fungi occur on dead and dying leaves and stalks.

INGA spp.

Perisporium truncatum F. L. Stevens. Black mildew on living leaves of *Inga preusii* Harms, vicinity of San Salvador, P. C. Standley.

Ravenelia ingae (P. Henn.) Arth. A rust on leaves and twigs of *Inga preusii* Harms, often causing malformations. La Ceiba, no. 368, on *Inga* sp. La Ceiba, no. 338; near San Salvador, P. C. Standley, no. 22461. The latter specimen was originally named as *R. whetzelii* Arth., now considered synonymous with *R. ingae*.

Virus. A possible virus disease producing a mottling of leaves of *Inga* sp. was observed at the La Ceiba Exp. Stat., nos. 334, 335, 336.

LACTUCA SATIVA L. Lettuce.

Septoria lactucae Pk. Leaf spot causing defoliation. La Ceiba, nos. 15, 194.

LYCOPERSICUM ESCULENTUM Mill. Tomato.

Cladosporium fulvum Cke. This common and often destructive leaf mold occurred on both native and introduced types. La Ceiba Exp. Stat. no. 81; Herredura, no. 391; Izalco, no. 421.

Septoria lycopersici Speg. Leaf spot was very severe on certain varieties, particularly the small fruited native type, near Volcan de Izalco, no. 175.

MANGIFERA INDICA L. Mango.

Colletotrichum gloeosporioides Penz. Mango anthracnose is common wherever the tree is grown, causing a blackening of the fruit. Young leaves are distorted and large, irregular deep brown blotches are produced on more mature ones. La Ceiba Exp. Stat., on fruit and leaves, no. 32; near Panchamalco, no. 397.

Phyllosticta mortoni Fairman. This fungus causes a leaf spot characterized by numerous, small, angular gray spots with definite dark-brown margins. Previously reported from Florida, Puerto Rico, Cuba, Guatemala, and Mexico. Sonsonate, no. 187; Finca Santa Ana, San Miguel, no. 211.

MANIHOT ESCULENTA Crantz. Manihot, yuca, cassava.

Cercospora henningsii Allesch. This fungus causes brown circular to irregular spots and blotches on the leaves, 5 mm or more in diameter in contrast to the small (2–3 mm) definite spots with white centers due to *C. caribaea* Cif. Near Mercedes, Umaña, no. 411; near Izalco, nos. 422, 423.

Odium manihotis P. Henn. The powdery mildew of this host is in the *Oidium* stage only, producing irregular light brown blotches on the leaves with a white powdery layer showing beneath. Also known from Central Africa, Brazil, and Peru. La Ceiba, no. 291.

Phyllosticta sp. Associated with small (1–2 mm) leaf spots, silvery white above, reddish brown beneath. Along shores of Lake Ilopango, no. 381.

Virus. Typical mottling, stunting and malformation of the *Marmor* type, associated with aphids. La Ceiba Exp. Stat., no. 290; near Mercedes, Umaña, nos. 412, 413.

MEDICAGO SATIVA L.[3] Alfalfa.

Bacterium alfalfae Riker, F. R. Jones & Davis (?). Bacterial leaf spot has been known heretofore only from the United States. Specimens from Santa Tecla, nos. 117, 118, 119, are doubtfully referred to this species.

Cercospora sp. (probably *C. zebrina* Pass.) Leaf spot. Santa Tecla, no. 117.

Rhizoctonia sp. Associated with bleached spots on stems. Santa Tecla, no. 120.

Uromyces striatus Schroet. The rust is common and widespread on this host in El Salvador but not serious. Santa Tecla, nos. 116, 118.

MELICOCCA BIJUGA L. Spanish lime.

Virus. An undetermined virus causing severe mottling of leaves. La Ceiba, no. 90.

MUSA PARADISIACA L. Banana.

Cercospora musae Zimm. The "sigatoka" disease of bananas, which has caused heavy losses in many banana-growing countries was collected at La Ceiba, no. 79, and at Tomatopeque, no. 438.

Cordana musae (Zimm.) Hoehn. Cordana leaf spot attacking the "Cavendish" variety, Los Planos, no. 2.

PACHYRHIZUS sp. Jicama.

Isariopsis griseola Sacc. This species, causing an angular leaf spot, is usually confined to *Phaseolus* and its reference to *Pachyrhizus*, a new host genus is somewhat doubtful. However it does not appear to differ morphologically from the form on *Phaseolus*. La Ceiba, nos. 99, 100, 455.

[3] All determinations of organisms on *Medicago* are by C. Lefebvre.

PANICUM spp. Panicum grasses.

Cercospora fusimaculans Atk. A leaf-spot disease characterized by linear brown spots on Guinea grass (*Panicum maximum* Jacq.). San Andres, no. 357; Zacatecoluca, no. 433. Previously known from Colombia, Panama Canal Zone, and Brazil as well as the southern United States.

Uromyces leptodermus Syd. Rust on leaves of *Panicum purpurascens* Raddi (*Panicum barbinode* Trin.) Pará grass. Near San Salvador, Standley, no. 19677.

PASPALUM spp.

Claviceps paspali F. L. Stevens & J. G. Hall. This common *Paspalum* ergot fungus, which is poisonous to livestock, was collected at Montserrate, no. 485, on *Paspalum* sp.

PASSIFLORA QUADRANGULARIS L. Granadilla.

Cercospora regalis Tharp. Leaf spots. La Ceiba, no. 34.

PERSEA spp. Avocado and relatives.

Cercospora purpurea Cke. (?). The common leaf-spot-producing fungus of the avocado (*Persea americana* Mill.) is tentatively assigned to this species, pending more detailed study. It produces numerous, small, angular, dull brown spots and has been previously known from the state of Florida. A possible perfect stage (*Mycosphaerella*) has been reported by H. E. Stevens from that State. La Ceiba, no. 462.

Cephaleuros virescens Kunze. The algal leaf spot was common and abundant on *Persea schiedeana* Nees, an avocado relative, intermingled with *Strigula complanata* Fee, a leaf inhabiting lichen. Santa Tecla, nos. 115, 116.

PETROSELINUM CRISPUM (Mill.) Nym. Parsley.

Cercospora apii Fres. Leaf spot. Slopes of Volcano de San Salvador, no. 340.

PHASEOLUS LUNATUS L. Lima bean.

Elsinoë phaseoli Jenkins. Lima bean scab was found on the leaves and pods of a specimen collected by S. Calderon, San Salvador, and deposited at the Gray Herbarium, Cambridge, Mass. (Phytopathology 23: 602. 1933).

PHASEOLUS VULGARIS L. Bean.

Chaetoseptoria sp. See discussion of this fungus under *Vigna* (cowpea). La Ceiba, nos. 126a, 126b, 128.

Isariopsis griseola Sacc. Angular leaf spot is common on beans in all localities and does some damage. La Molina, nos. 306, 307; Cuscutlan, no. 312, slopes of Volcano San Salvador, no. 343; near Izalco, no. 419.

Myrmaecium roridum Tode. On matured pods near Paraiso, no. 449.

Periconia pycnospora Fres. On matured pods, near Paraiso, no. 449a. Determined by E. K. Cash.

Uromyces phaseoli typica Arth. The universally distributed bean rust contributes directly to crop reduction by destruction of leaves. La Ceiba, no. 128; near Sacocoyo, nos. 136, 137; La Molina, Santa Ana, nos. 306, 307; near Izalco, no. 420; near Paraiso, no. 448; vicinity of San Salvador, collector Standley, nos. 19600, 23303. (Reported by Standley and Calderón (6) as *U. appendiculatus* [Pers.] Fr.)

Vermicularia polytricha Cke. On matured pods. Near Paraiso no. 449.

PHOENIX sp. Palm.

Graphiola phoenicis (Moug.) Poit. The false smut of *Phoenix* and related palms is omnipresent and always disfiguring. La Ceiba, no. 16.

PITHECELLOBIUM DULCE (Roxb.) Benth.

Microstroma pithecolobii Lamkey. This fungus, causing a leaf mold disease, has been known previously only from Puerto Rico on *Samanea saman* (Jacq.) Merr. La Ceiba, no. 86.

Virus. Causing a yellow mottling of leaves. La Ceiba, no. 87.

PRUNUS PERSICA (L.) Batsch. Peach.

Tranzschelia pruni-spinosae (Pers.) Diet. The peach leaf rust occurs co-extensively with its host and is often a serious defoliator. Los Planos near San Salvador, no. 6; slopes of Volcano San Salvador, no. 344. The latter specimen is parasitized by *Darluca filum* (Biv.) Cast., which possibly helps to keep the rust in check.

PSIDIUM GUAJAVA L. Guava, Guayaba.

Meliola psidii Wint. Black mildew on leaves, common, but not serious. San Salvador, P. C. Standley, collector.

PUNICA GRANATUM L. Pomegranate.

Cercospora punicae Syd. Leaf spot, not serious. C. *lythracearum* Heald & Wolf is synonymous. La Ceiba, no. 492.

RAPHANUS SATIVUS L. Radish.

Albugo candida Pers. ex Kuntze. The white rust is common and widespread, but seldom destructive, wherever the host is grown. La Ceiba Exp. Stat., no. 73.

RICINUS COMMUNIS L. Castor bean.

Cercospora ricinella Sacc. & Berl. This common leaf spot producing fungus characterized by numerous, small circular to angular, white centered spots causes severe defoliation at times. San Andres, nos. 198, 199, 200; San Miguel, no. 216.

ROSA spp. Rose (cultivated varieties).

Actinonema rosae (Lib.) Fr. This common and widespread disfiguring leaf spot disease known as "black spot" was collected at the La Ceiba rose garden, no. 23 and at Cuscutlan, no. 314. The fungus also has a perfect stage (*Diplocarpon rosae* Wolf) not yet found in Salvador.

Cercospora puderi B. H. Davis. This fungus causes small spots (up to 4 mm in diameter) with gray centers. La Ceiba rose garden, nos 24, 25. This species has been previously known from the southern United States and Mexico, but is much less common than the ubiquitous *C. rosicola* Pass., which is characterized by larger spots and with sporulation on both surfaces.

Diplodia sp. Associated with dieback. La Ceiba Exp. Stat., nos. 66, 67.

Stilbella cinnabarina (Mont.) Wr. Fruiting on dead and dying stems of *Rosa odorata* Sweet. La Ceiba rose garden, no. 69.

RUBUS spp.

Elsinoë veneta (Burk.) Jenkins. Anthracnose on stems and leaves of a blackberry (*Rubus* sp.) near the top of Volcano San Salvador, no. 347. The imperfect stage only (*Sphaceloma*) of the fungus was present. Determination by Anna E. Jenkins.

Spirechina rubi (Diet. & Holw.) Holw. Rust on leaves of *Rubus adenotrichos* Schlecht. Volcan de San Salvador, collector P. C. Standley.

SACCHARUM OFFICINARUM L. Sugarcane.

Leptosphaeria sacchari V. B. de Haan. The "ring spot" disease due to this fungus is common on older leaves, as in all other cane growing countries. La Cabana, nos. 221, 231.

Virus. Mosaic (*Marmor sacchari* Holmes) is prevalent and severe throughout the country on susceptible varieties.

SALIX CHILENSIS Mol. Willow.

Melampsora abieti-capraearum Tub. (*Melampsora humboldtiana* Speg.) Rust on leaves. Ahuachapán, Dept. de Ahuachapán, Standley, 20255.

SECHIUM EDULE Sw. Chayote, huisquil.

Rhagadolobium cucurbitacearum (Rehm) Th. & Syd. Tar spot disease of the leaves, disfiguring, but seldom serious. La Ceiba, no. 70.

SOLANUM spp.

Cercospora diffusa Ell. & Ev. Black leaf spot on *S. nigrum* L. Shores of Lake Ilopango, no. 384.

Cercospora solani-torvi Frag. & Cif. Leaf spot on *Solanum* sp. (probably *S. torvum* Sw.), near Zaragoza, no. 402.

SORGHUM HALEPENSE (L.) Pers. (*Holcus halepensis* L.) Johnson grass.

Cercospora sorghi Ell. & Ev. Causing a leaf spot near Herradura, no. 395.

Gloeocercospora sorghi Bain & Edgerton. Leaf blotch, a disease heretofore known only from the southern United States. La Laguna, no. 322.

Helminthosporium turcicum Pass. La Laguna, no. 322.

Puccinia purpurea Cke. The rust was collected by S. Calderón, no. 41a.

SORGHUM VULGARE (L.) Pers. (*Holcus sorghum* L.) Sorghum.

Cercospora sorghi Ell. & Ev. Leaf spots, common at La Ceiba, no. 132.

Colletotrichum graminicolum (Ces.) G. W. Wils. Anthracnose. West of San Vicente, no. 208; near San Jose del Sacario, no. 443. World wide on most species of grasses.

Helminthosporium turcicum Pass. Leaf spot and blotch. La Ceiba, no. 132.

Puccinia purpurea Cke. Very common everywhere on this host, producing large irregular, deep red blotches on leaves. La Ceiba, Puerta, no. 375.

Virus. Near sugarcane fields, where sugarcane mosaic (*Marmor sacchari* Holmes) was present, and hence the same virus is probably involved here. Santa Tecla, no. 269.

SORGHUM VULGARE var. SUDANENSE (Piper) Hitchc. (*Holcus sudanensis* Piper). Sudan grass.

Cercospora sorghi Ell. & Ev. Leaf spot. La Ceiba, nos. 131, 133, and 135.

TECOMA STANS (L.) H. B. K.

Prospodium appendiculatum (Wint.) Arth. Rust common on the leaves of this ornamental

tree. Ahuachapán, Dept. de Ahuachapán, Standley 19905; near San Martín, Dept. de San Salvador, 22590.

TETRAGONIA EXPANSA Thunb. New Zealand spinach.

Cercosporina tetragoniae Speg. Leaf spot. Slopes of Volcano San Salvador, no. 348.

TRITICUM AESTIVUM L. Wheat.

Puccinia rubigo-vera tritici (Erikss. & P. Henn.) Carleton. Both stages (uredial and telial) of this common leaf rust of wheat were found. Slopes of Volcano San Salvador, nos. 247, 248, 249, and 353.

Septoria tritici Rob. A scanty collection of this common wheat parasite was made on the slopes of Volcano San Salvador, no. 353.

VIGNA SINENSIS (Torner) Savi. Cowpea.

Cercospora canescens Ell. & Martin. Leaf spot near Sacocoyo, nos. 140, 143.

Chaetoseptoria sp. This fungus was associated with large, circular leaf spots. Tehon described (Mycologia 29: 444–445. 1937) the genus as new and established the species *C. vignae* on *Vigna sinensis*. The Salvador fungus has conidia up to 150μ long in contrast to 18–50μ reported by Tehon for those of *C. vignae*. The pycnidia are also much larger than those of the Illinois fungus. Near Sacocoyo, no. 140; Zapitotan, no. 424.

Erysiphe polygoni DC. This powdery mildew, in the *Oidium* stage only, as is usual in tropical collections, was collected at Los Planos, near San Salvador, no. 3.

VITIS VINIFERA L. Grape.

Alternaria vitis Cav. Associated with leaf spots. Los Planos, near San Salvador, no. 8.

Mycosphaerella sp., in circular light-brown leaf spots, with dark brown definite borders. La Laguna, no. 325.

Physopella vitis (Thuem.) Arth. The grape rust, also known as *Phakopsora vitis* (Thuem.) Syd., occurs commonly on vinifera grapes, causing some defoliation; the fungus also is present in the southern United States, the West Indies, Guatemala, and northern South America. Los Planos, near San Salvador, no. 7; Santa Ana, no. 308; San Salvador, no. 463.

YUCCA ELEPHANTIPES Regel. Izote.

Didymosphaeria sp. A species, distinct because of its larger spores from *D. yuccogena* (Cke.) Sacc. and *D. clementsii* Sacc. & D. Sacc., causing leaf spots was found on the lower slopes of Volcan de San Salvador, no. 267.

Gloeosporium sp. (*Gl. yuccigenum* Ell. & Ev.?) Anthracnose of leaves, forming large concentrically zoned diseased areas. Lower slopes, Volcan de San Salvador, nos. 266, 267.

Leptosphaeria obtusispora Speg. The fungus produces large, irregular, dull brown blotches on the leaves. It differs from the more common *L. filamentosa* Ell. & Ev. in its 5-septate spores as contrasted to the 3-septate spores of the latter species. La Ceiba, no. 332.

Sphaerodothis pringlei (Pk.) Th. & Syd. Tar spot fungus on leaves. On lower slopes, Volcan de San Salvador, no. 267; slopes of Volcan San Salvador, no. 354.

ZEA MAYS L. Corn, maize.

Angiopsora zeae Mains. This is one of the rarer rust fungi occurring on *Zea*, heretofore reported as found sparingly in Puerto Rico, the Dominican Republic, Guatemala, and Trinidad. For a discussion of this and certain of the other corn rusts see article by G. B. Cummins (Phytopath. 31: 856–857. 1941). Zapotitan, nos. 360, 361 (both uredial and telial stages.)

Cercospora sorghi Ell. & Ev. A common leaf spot producing fungus. La Ceiba, nos. 378, 379; near Herradura, no. 394. Distinct from *C. zeae-maydis* Tehon and Daniels, which is described with conidia 5–9μ wide, in contrast to 3μ as described for the former.

Cladosporium herbarum Lk. Associated with large irregular, dead areas on leaves, near San Estabán, nos. 409, 429. Other fungi present were *Alternaria* sp., *Fusarium* sp., *Periconia* sp., and *Nigrospora oryzae* (Berk. & Br.) Petch all possibly secondary.

Curvularia geniculata (Tracy & Earle) Boed. Associated with elongated brown lesions on leaves. La Cabana, no. 237.

Diplodia zeae (Schw.) Lév. Ear rot. La Ceiba, no. 373.

Fusarium sp. Associated with ear rot and occurring also with other molds on leaves and husks. La Ceiba, no. 372.

Helminthosporium turcicum Pass. A very common and widespread fungus on maize in Salvador and one that apparently causes much damage by destroying leaves. Secondary fungi quite commonly are present also on diseased material. Near Sonsonate, nos. 151, 152; near

Izalco, no. 177; Zapotitan, nos. 188, 189; San Andrés, nos. 159, 164, 193, 194, 195; La Cabana, nos. 235, 238; La Ceiba, no. 377; near San José del Sacario, no. 444.

Nigrospora oryzae (Berk. & Br.) Petch. Associated with leaf spots, and cob rot, La Union, no. 429.

Physoderma zeae-maydis Shaw. This fungus causes the disease known as brown spot. It is an important and widespread disease of corn in tropical and subtropical countries, there being reports of its occurrence in China, India, Central Africa, Brazil, and Guatemala. Although described originally from India, it is doubtless of American origin and Tisdale (Journ. Agr. Res. 16: 137–154. 1919) says of it, "It is possible that the disease was introduced into the United States from Mexico or Central America with *Euchlaena mexicanum.*" *Physoderma maydis* Miy. described from Japan does not appear to differ. The Salvador material is typical both in the disease symptoms and in the morphology of the fungus except that the sporangia are somewhat smaller (15–18 by 15–21μ) than those described by Tisdale. Near Sonsonate, no. 176; near Izalco, no. 177; La Ceiba, nos. 123, 125; San Andrés, nos. 160, 161, 164, 194; Zapotitan, no. 367.

Puccinia pallescens Arth. A second species of rust found sparingly in the uredial stage only at Los Planos, near San Salvador, no. 1.

Puccinia polysora Underw. The third species of corn rust prevalent in the country. Found in both uredial and telial stages, near Talchalaya, no. 446; and near Paraiso, no. 447.

Puccinia sorghi Schw. The most common and widespread of the four species of rust attacking *Zea*. Collected around the edge of the crater of Volcano de San Salvador, nos. 253–258. The rust on several of the specimens is overgrown by the ubiquitous rust parasite, *Darluca filum* (Biv.) Cast.

Ustilago maydis (DC.) Cda. (*U. zeae* [Beckm.] Unger.). The common corn smut occurs abundantly as in all corn growing countries. La Ceiba, no. 370; near Izalco, no. 436; near Paraiso, no. 451.

Virus. An undetermined virus disease causing a mottling of leaves was noted near Sonsonate, no. 174.

ZINNIA ELEGANS Jacq. (*Crassina elegans* [Jacq.] Kuntze). Zinnia.

Cercospora zinniae Ell. & Martin. This leaf spot fungus causes serious defoliation of the zinnia in El Salvador. *C. atricincta* Heald & Wolf, named from Texas, does not appear distinct. La Ceiba Exp. Stat., nos. 62, 76; Sonsonate, no. 180.

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ENTOMOLOGY.—*A new species of* Anopheles *from the Solomon Islands.*[1] JOHN N. BELKIN and RALPH J. SCHLOSSER, Sanitary Corps, U. S. Army. (Communicated by ALAN STONE.)

In the Lunga district of Guadalcanal Island, British Solomon Islands Protectorate, a survey of the anophelines was made. Four distinct forms of anophelines were encountered, a species of *Bironella* (*walchi?*), two forms of *A. punctulatus* Dönitz, and a species of *Anopheles*, which is described herewith. In reports from this area in the past few months this species has been called *A. p. punctulatus* Sw. & Sw. Investigations of the role of *A. p. punctulatus* in the transmission of disease on this island were actually carried out with this new species and not with *A. p. punctulatus* as reported. A summary of these investigations is given at the end of the paper. The senior author was very for-

[1] Received June 29, 1944.

tunate in enlisting the assistance of the junior author in the preparation of the illustrations.

Anopheles (Myzomyia) lungae, n. sp.

Adult female.—A medium-sized yellowish, speckled anopheline with the apical third of the labium yellow. Length of wing 4 mm.

HEAD (Fig. 2): Conspicuous white frontal tuft; vertical setae white, followed by one or two rows of white narrow hair-like scales; white scales on top of vertex forming a wide spot narrowed in the center; the rest of vertical scales and the occipital scales dark. Antenna with a few minute white scales on torus and dense white scaling on the first flagellar segment. Palpi ornamented as shown in Fig. 2; ornamentation very constant, the light scales yellowish on the last segment and white on the rest. Labium densely covered with yellow scales on apical third, yellow coloration broken by narrow dark ring just proximad of apex. Labella dull yellow.

THORAX (Fig. 3): White scales on anterior promontory rather short and scarce, central scales elongate, lateral broader. A few dark scales below. Rest of mesonotum devoid of scales, except for very narrow whitish scales in front of wing root; vestiture consisting of numerous golden hairs of varying length. Mesonotal integument light brown with gray pollinose longitudinal lines; dark brown eye spots in front of and behind scutal angle; prescutellar space dark brown. Mesonotal bristles light in color. Pleura darker with a broad blackish longitudinal line dorsally. Spiracular bristles absent, propleurals 6, lower sternopleurals 3, upper sternopleural 6–8, prealars 4–6, subalars 5–6, lower mesepimerals absent.

WING (Fig. 1): As in figure; pale areas light yellow, dark spots often more conspicuous than shown in figure, scales rather broad. Median dark spot includes base of vein 2; a dark spot on costa between basal and median dark spots; subcosta and vein 1 without dark spots in this area; small black spots, shown in figure, between median and preapical black spots sometimes absent.

LEGS (Fig. 4): Front femora swollen in basal half, speckled; middle and hind femora and all tibiae with rather evenly spaced pale spots externally. First segment of front tarsus with several light spots and light apex; second, third and fourth segments with basal and apical light bands; fifth segment dark basally, remainder light. First segment of middle tarsus similar to corresponding segment of front tarsus; second, third and fourth segments with basal light bands only; fifth segment all dark. First segment of hind tarsus with numerous light spots and light apex, second segment with light apical band and usually one to three light spots in the center; third segment with light apical band and occasionally a few light scales in center; fourth segment with light apical band; fifth segment all dark. Light scales on legs yellowish. Dark scales on middle tarsus much lighter than on other tarsi.

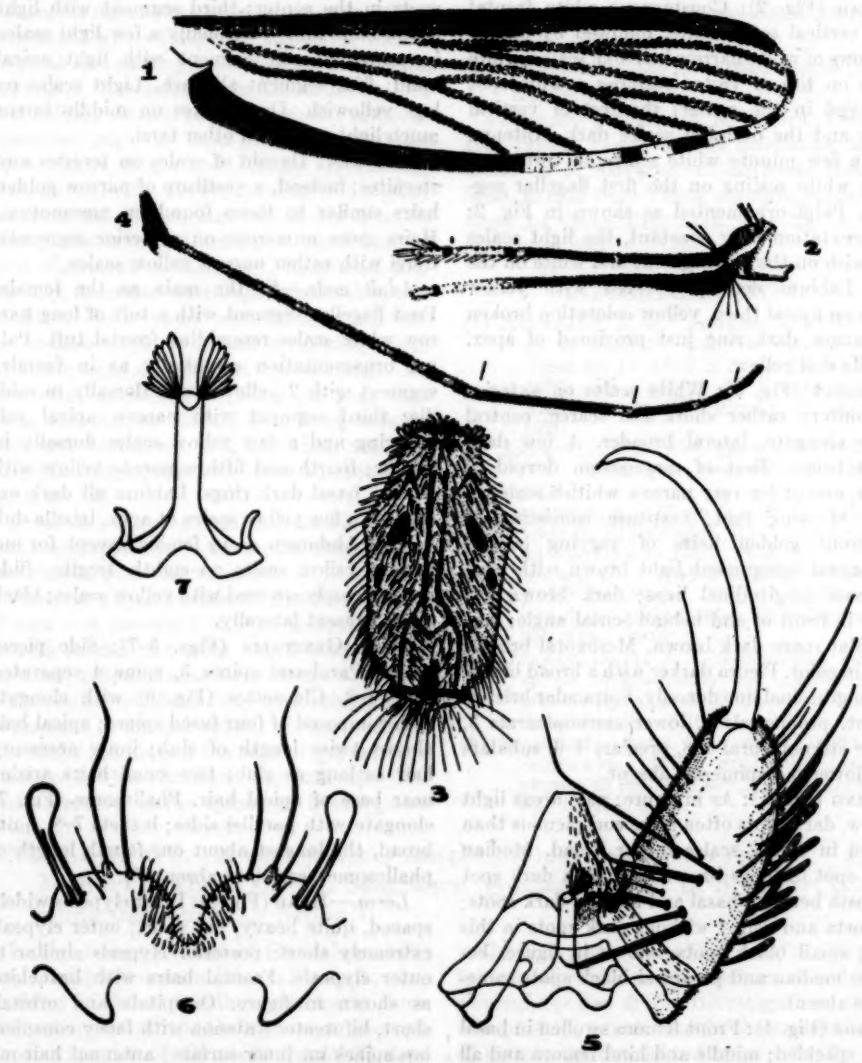
ABDOMEN: Devoid of scales on tergites and sternites; instead, a vestiture of narrow golden hairs similar to those found on mesonotum. Hairs more numerous on posterior segments. Cerci with rather narrow yellow scales.

Adult male.—In the main as the female. First flagellar segment with a tuft of long narrow white scales resembling frontal tuft. Palpal ornamentation essentially as in female; segment with 2 yellow scales dorsally in middle; third segment with narrow apical yellow ring and a few yellow scales dorsally in middle; fourth and fifth segments yellow with narrow basal dark rings. Labium all dark except for a few yellow scales at apex, labella dull yellow. Abdomen as in female except for numerous yellow scales on eighth tergite. Side pieces densely covered with yellow scales; black scales present laterally.

MALE GENITALIA (Figs. 5–7): Side pieces broad. Parabasal spines 5, spine 4 separated from 1–3. Claspettes (Fig. 6) with elongate club composed of four fused spines; apical hair almost twice length of club; inner accessory hair as long as club; two small hairs arising near base of apical hair. Phallosome (Fig. 7) elongate with parallel sides; leaflets 7–8, quite broad, the longest about one-fourth length of phallosome, serrations absent (?).

Larva.—HEAD (Fig. 8): Inner clypeals widely spaced, quite heavy, but short; outer clypeals extremely short; posterior clypeals similar to outer clypeals. Frontal hairs with branching as shown in figure. Occipitals and orbitals short, bifurcate. Antenna with fairly conspicuous spines on inner surface; antennal hair minute arising one third from base; terminal hair with about five branches arising from base, slightly longer than sabers; basal hair normal; subbasal short, three branched.

THORAX (Fig. 9): Prothoracic hair 1 with heavy basal tubercle, heavy shaft and radiation branching, approximately half as long as hair 2; hair 2 not quite so long as hair 4, with heavy basal tubercle, heavy shaft, and five to six branches on each side; hair 3 small, simple; hair 5 with very thick shaft, minute lateral branches except near apex where branches are long; hair 6 simple, longer than 5. Prothoracic pleural hairs 9 and 10 long and simple; hair 11 long with three to five branches; hair 12 simple or bifid, about one-third length of long hairs. Mesothoracic pleural hairs 9 and 10 long and simple; hair 11 short, with two or three



MORPHOLOGY OF ADULT ANOPHELES LUNGAE

Fig. 1.—Wing of female. Fig. 2.—Mouthparts of female. Fig. 3.—Mesonotum of female. Fig. 4.—Hind tarsus of female. Fig. 5.—Male genitalia. Fig. 6.—Claspettes. Fig. 7.—Phallosome.

branches, hair 12 minute. Hair 1 on mesothorax with thickened shaft. Hair 1 on metathorax forming a palmate hair with approximately 8 leaflets, leaflets not pigmented.

ABDOMEN (Fig. 9): Palmate hairs very large and heavily pigmented on segments III–VII, somewhat smaller on VII; poorly developed on I; fairly well developed (12 or more leaflets) but lightly pigmented on II. Leaflets (Fig. 11) numbering 16 to 26 on segment III and IV, well-pigmented; filaments short, indentations not numerous. Lateral hair on segment III with approximately six branches on each side, arising well away from base; lateral hairs on segments IV and V usually double; lateral hairs on VI with five to six branches. Anterior tergal plates rather small; posterior tergal plates very small, present on segment IV–VII. Median plate of scoop well developed. Pecten (Fig. 10) with 3–4 long and 6–8 short spines, the serrations at their bases very fine and inconspicuous; the pecten hair with 4–5 branches. Caudal hooks 6–8. Anal gills much longer than anal segment.

Types.—Holotype ♀, allotype ♂, paratypes 20 ♀, 20 ♂ collected resting on tree trunks, Tassafaronga Swamp, Guadalcanal Island, January 28, 1944 (Belkin); paratypes 5 ♀, 4 ♂ reared from larvae collected in Wright's Creek, Guadalcanal Island, November 11, 1943 (Belkin); paratypes 10 ♀, 15 ♂ collected on tree trunks, Burns Creek, Lunga, Guadalcanal Island, March 10, 1944 (Belkin). Holotype and allotype to be deposited in U. S. National Museum.

Identification.—This species can be separated easily from the forms of *A. p. punctulatus* in both the male and female by the very large median dark spot on the wing, the yellowish scales on the wings and palpi, the absence of white scales on most of the mesonotum and the presence in their place of yellow hairs. The larvae are easily distinguished by the very short outer clypeals, simple inner clypeals, the very characteristic prothoracic hairs 1 and 2, the palmate hairs, and the pecten. On pleural hairs this species does not quite agree with other members of the group *Myzomyia* to which it apparently belongs. The combination of characters exhibited by this species is not found in any previously described form. Seventy individual rearings of larvae established the identity of this form.

Distribution.—*Anopheles lungae* is generally distributed along the northwest coast of Guadalcanal Island. It may be present also on some of the other Solomon Islands.

Biology.—The larvae of this species are normally found in the jungle in seepage areas, along the margins of streams, pot holes in stream beds, rock holes, dense jungle swamps, and temporary pools. The species has a decided preference for shade in its breeding places. During the rainy season the larvae are flushed out into the coconut groves on the coastal strip where the species then breeds. The diurnal adult resting places were first discovered by Capt. F. B. Whittington. Adults are usually found resting in partial shade on tree trunks in the jungle. Males, unfed, blooded, and gravid females are all found together. Other resting places have been found under logs, inside crates, boxes, oil drums, foxholes, and nail kegs.

As this species becomes very abundant early in the rainy season on the northwest coast of Guadalcanal, preliminary investigations were conducted on its feeding habits and its relation to disease transmission in this area. On several occasions areas with a high adult density of this species were visited at night and biting records made. Males and females were observed leaving their daytime resting places between 6:30 and 7:00 P.M.; after 7:30 none could be found resting. Although the biting records were made among the trees where the anophilines were resting, less than two percent of the total anopheline catch was *A. lungae*. In routine night catches for anophelines in the Lunga district of Guadalcanal the percentage of *A. lungae* of the total anophelines collected is a little less than two. Blooded females collected in the jungle near troop areas were dissected. Seventy percent of these showed nucleated red blood cells; the blood found in the remainder was of mammalian origin. Precipitin tests are being made on a small number of blooded females of these species collected by Capt. F. B. Whittington.

It appears from these sketchy observations that in the area in question *A. lungae* is not strongly androphilic and probably is not of primary importance in disease transmission. Nevertheless, during the rainy season when this species is flushed out by the rains and extends its breeding range into the coastal coconut

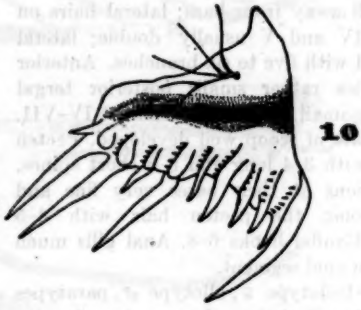
groves it may become a problem locally. The normal blood supply is believed to be birds and possibly bats. With the great disturbance caused by an influx of humans a change in blood feeding habits may take place.

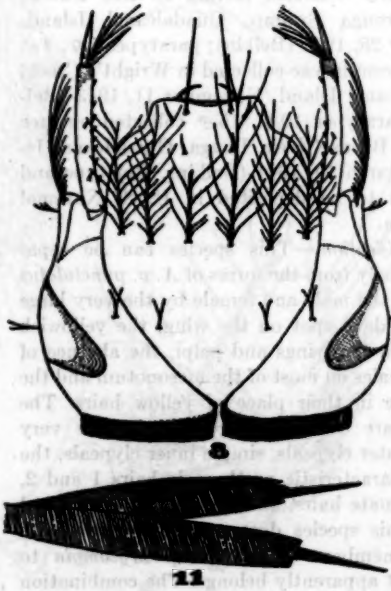
PROVISIONAL KEYS TO ANOPHELINES OF GUADALCANAL ISLAND

The following provisional keys are included as it is hoped that they may be of assistance in other parts of the South Pacific Area. Large series of individual rearings connected the larvae with the adults.

Females

1. Palpi very short, wing scales all dark..... .....*Bironella*(*walchi*?)
   Palpi as long as labium, wing scales light and dark.....2
2. Mesonotum with a vestiture of golden yellow hairs only, except for white and black scales on anterior promontory; median dark wing spot including subcosta, vein 1, and base of vein 2; apical third of proboscis with yellow





MORPHOLOGY OF LARVA OF ANOPHELES LUNGAE

Fig. 8.—Head. Fig. 9.—Thorax and abdomen. Fig. 10.—Pecten. Fig. 11.—Leaflet of palmate hair.

scales, interrupted by narrow dark ring near apex.....*A. lungae*
Mesonotum with a vestiture of white scales throughout; median dark wing spot not extending to veins 1 and 2.....3
3. Labium all dark except for a few white or yellowish scales at extreme apex...*A. p. farauti*
Labium with a vestiture of white or creamy scales on apical third, interrupted by a narrow ring of dark scales just before apex.....*A. p. punctulatus*

Males

The males of the three forms of *Anopheles* in this area have the labium all dark with a few light scales on apex; the labella are dull yellow. The males of *A. lungae* can be distinguished on mesonotal vestiture and wing spotting which are similar to the female. The males of *A. p. punctulatus* and *A. p. farauti* have not as yet been successfully separated.

Larvae

1. Inner clypeals close together.*Bironella(walchi?)*
Inner clypeals widely separated.....2
2. Outer clypeals extremely short, usually less than one quarter the length of inner clypeals; pecten with two distinct series of spines, spines 10–12 in number; palmate hair on II not pigmented.....*A. lungae*
Outer clypeals at least half as long as inner clypeals; pecten with 14–17 subequal spines 3
3. Clypeal hairs slender, without branches; prothoracic hairs 1 and 2 with rather slender shafts, hair 5 with long lateral branches; palmate hair on II less developed than on III; lateral hairs on IV and V with three to four branches.....*A. p. punctulatus*
Clypeal hairs thickened, with a few fine lateral branches; prothoracic hairs 1 and 2 with thickened shafts, hair 5 with very short lateral branches; palmate hair on II developed as strongly as on III; lateral hairs on IV and V simple or double..*A. p. farauti*

Remarks.—The larvae of *A. p. punctulatus* from Guadacanal agree in every respect with the chaetotaxy represented for this form in Ross and Roberts' "Mosquito Atlas," Part 2, p. 12, 1943. Adults of *A. p. punctulatus* have never been collected attempting to bite humans on this island.

ENTOMOLOGY.—*Some relationships of* Anopheles lungae *Belkin and Schlosser (Diptera: Culicidae).*[1]

ALAN STONE, U. S. Bureau of Entomology and Plant Quarantine.

The foregoing excellent description of *Anopheles lungae* is sufficient to distinguish it from all other described species, but it seems advisable to compare it with certain closely related species that were not available to its describers. This is particularly true since it might be confused with *Anopheles tessellatus* Theobald or *A. longirostris* Brug. These three species have the following characters in common which distinguish them from the related species, *punctulatus* Dönitz, *annulipes* Walker, *farauti* Laveran, and *amictus* Edwards: (1) Scales of the halteres entirely pale, creamy white; (2) scutum with scales on the anterior margin only; (3) outer clypeal hairs of the larva very short, much less than half as long as the inner clypeal hairs.

The females of the two close relatives of *lungae* are distinguished from it by the following characters:

A. longirostris: At least apical half of proboscis pale; proboscis about one-fifth longer than the palpi, strongly decurved; third palpal segment (antepenultimate) with apical half pale.

A. tessellatus: Third palpal segment with apical half pale.

The larva of *lungae* closely resembles that of *tessellatus*, but prothoracic hair 1 of *tessellatus* has a slender shaft with 2–6 branches. The larva of *longirostris*, as described, shows no differences from *lungae*, but it is quite probable that a direct comparison of the two species will reveal some.

The distribution of these three species is of some interest in view of their close relationship. *A. tessellatus* has a wide Oriental distribution from India to Hong Kong, the Netherlands Indies, the Philippines, with a few records from the Moluccas, and one questionable one from western New Guinea. *A. longirostris* has been collected from several places in New Guinea and from Kavieng, New Ireland. *A. lungae* is confined to the Solomon Islands. The distribution of the three species has not yet been found to overlap.

Received June 29, 1944.

ICHTHYOLOGY.—Sphyrna bigelowi, *a new hammerhead shark from off the Atlantic coast of South America, with notes on* Sphyrna mokarran *from New South Wales.*[1]

STEWART SPRINGER, Homestead, Fla. (Communicated by LEONARD P. SCHULTZ.)

During a study of sharks in the collections of the Museum of Comparative Zoology, Dr. Henry B. Bigelow and William C. Schroeder found a single specimen of a hammerhead shark that they recognized as belonging to an undescribed species. Subsequently, when I found two specimens of this species in the United States National Museum collections, descriptive data and drawings of the M.C.Z. specimen were generously furnished by the discoverers. It gives me great pleasure to name this new hammerhead in honor of Dr. Bigelow in recognition of his part in the preparation of the important work on sharks in the forthcoming volume, "Fishes of the Western Atlantic."

Sphyrna bigelowi, n. sp.

Holotype.—Young male, about 385 mm in total length, collected by Dr. W. L. Schmitt on the coast of Uruguay, U.S.N.M. No. 87682.

Paratypes.—Young male about 395 mm, from the coast of Uruguay, U.S.N.M. No. 120751; female about 900 mm in total length, from Rio de Janeiro, Brazil, M.C.Z. No. 463.

Description.—Moderate size at birth (smaller at birth than *Sphyrna tudes* (Cuvier), *S. zygaena* (Linnaeus), or *S. diplana* Springer, but larger than *S. tiburo* (Linnaeus); body compressed, proportionately shorter bodied than other hammerheads; head flattened and expanded to form the hammer characteristic of genus; anterior margin of head divided by slight indentations into four lobes between the nostrils; deep groove (not visible from directly above or below) running from each nasal notch toward midpoint in forward margin of head for length of lobe adjacent to nostril; greatest width of head in smaller (newborn) individuals about 16 per cent and about 23 per cent of total length in largest (900 mm) specimen; anterior margin of head of smaller specimens rounded, that of large specimen less rounded; length of snout (distance from front of mouth to midpoint in front margin of the head) about 10 per cent of total length in smaller individuals and about 7.3 per cent in largest specimen; greatest length of expanded portion of head of smaller individuals about 50 per cent of its greatest width and in largest one about 40 per cent; posterior edge of hammer of young with relatively long trailing flap without cartilaginous support, this structure reduced in larger specimen; mouth broadly rounded and well back in head, a transverse line through front of mouth passing posterior to the eyes, a line through corners of mouth passing posterior to hinder edge of hammer in largest specimen but not posterior to trailing edge of hammer in young; eye small, its diameter about 1.5 per cent of total length in smaller specimens and proportionately smaller in the largest specimen; eye separated from nasal notch by a distance little greater than diameter of eye; gill openings of moderate length, first three nearly equal, last two a little shorter; last gill opening over insertion of pectoral; fins large, their distal (trailing) margins slightly concave except in pelvic fins which are rounded; caudal region heavy and compressed, caudal pits well developed; first dorsal fin high, roughly triangular, its origin behind axil of pectoral but in advance of free inner angle of pectoral; posterior lobe of first dorsal extending to a point over insertion of pelvics; no skin ridge along back between dorsal fins; second dorsal fin relatively high, its area about half that of anal fin; origin of second dorsal over middle of base of anal, and posterior lobe reaching a point about opposite posterior tip of anal but posterior tip of second dorsal when lifted upward not reaching a point much higher than apex of fin; base of anal fin long, with distal margin (free edge) not deeply incised, and apex a rounded point not greatly projecting; teeth in $\frac{16}{16}-\frac{0}{1}-\frac{16}{16}$ rows in types; all teeth without serrations; teeth of upper jaw narrowly triangular mostly directed toward corners of mouth and deeply notched on outer margins; teeth of lower jaw with narrower and more erect cusps, the latter only slightly pointing toward corners of mouth even in young;

[1] Received June 22, 1944.

base of lower symphyseal tooth and next four rows of lower jaw teeth with sharp shoulders in young; the sharp shoulders present only on symphyseal and first adjacent row of teeth in larger individual; fifteenth and sixteenth rows of teeth of lower jaw in the three type specimens without cusps.

Color.—In alcohol, grayish above and lighter below, no prominent contrasting markings except narrow yellowish border along anterior edge of hammer and yellowish cast to trailing edge of hammer in young (coloration possibly owing to preservation).

Comparison with other species.—If the diagnosis of the type material of *bigelowi* is correct, striking change in the shape of the head with growth is shown. All hammerheads, as judged by the material available for study show a tendency toward widening and shortening of the head with increase in size, and old adults of *bigelowi* may have the forward margin of the head nearly straight. The young of *S. tudes* have longer heads with more rounded anterior margins, but heads of the adults are nearly transverse. *S. bigelowi* and *S. tudes* are similar in regard to their small eyes, high second dorsal fins, and large mouths placed well back in head. *S. bigelowi* differs from *S. tudes* in having smooth instead of serrate teeth, a deep groove instead of a very shallow one in front edge of head, in the young having a long trailing edge of unsupported skin posteriorly along hammer. *S. bigelowi* has the smallest eye among all the species of the genus.

The combination of a deep groove along front margin of head and a relatively high second dorsal fin is not known in any other hammerhead shark. *S. bigelowi* differs from *S. zygaena* and *S. diplana* in having a higher second dorsal fin with a shorter posterior lobe instead of a lower fin with a longer posterior point. *S. bigelowi* has a low, long anal fin with its apex moderately projecting, whereas *S. tudes*, *S. zygaena*, and *S. diplana* have the anal

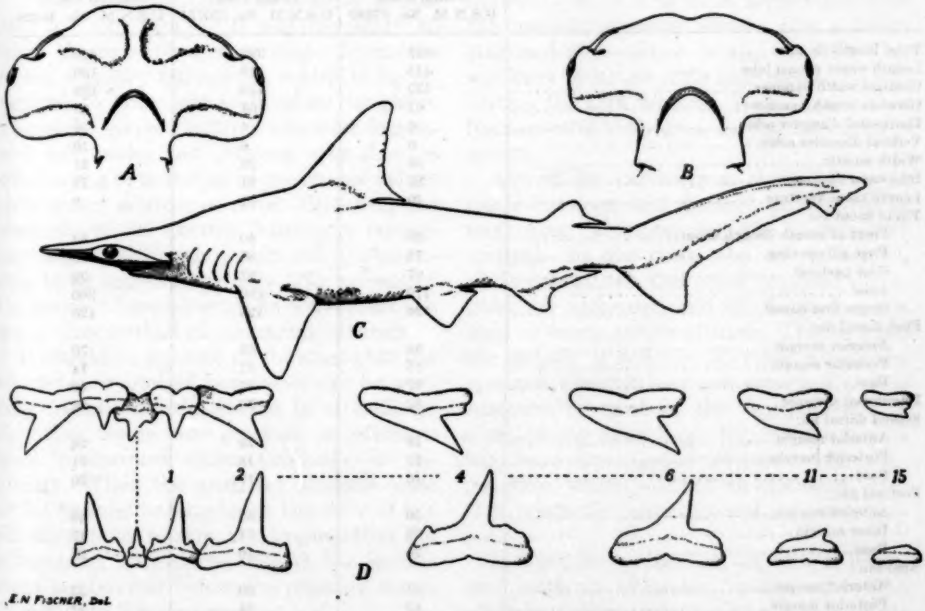


FIG. 1.—*Sphyrna bigelowi*, n. sp.: *A*, Lower side of the head of the holotype, U.S.N.M. No. 87682, a male, 385 mm in total length (the dotted lines mark the area of the trailing flap of the hammer); *B*, Lower side of the head of the 900-mm female; *C*, Lateral view of the holotype; *D*, Teeth of the 900-mm female; the lower symphyseal tooth, the first upper tooth of the right side of the jaw, and the upper and lower teeth of the left side of the jaw in the (1), (2), (4), (6), (11) and (15) rows are represented. Drawings by E. N. Fischer.

fin deeply incised distally, with the apex of the fin forming a distinct hook.

Sphyrna lewini (Griffith), *S. oceanica* (Garman), and *S. zygaena* are names that have been used for Pacific hammerheads. Regardless of the validity of these names the species represented all have small, low second dorsal fins with long posterior points, and thus differ from *S. bigelowi*. The Pacific species, *S. blochi* (Cuvier), *S. media* Springer, *S. corona* Springer, and *S. vespertina* Springer, and the Atlantic *S. tiburo* may be distinguished from *S. bigelowi* by the shape of the head.

Sphyrna mokarran (Rüppell) of the Red Sea, Indian Ocean, and the southwest Pacific Ocean is rare in collections and is not adequately described in the literature so it seems advisable to make a few notes here. Measurements of a female embryo of this species in fair condition, U.S.N.M. No. 40026, from Richmond River, New South Wales, February 7, 1889, are given in Table 1. Another specimen, 290 mm long, in poor state of preservation, U.S.N.M. No. 12622 from Madras, is tentatively identified as *S. mokarran*. *S. mokarran* is similar to *S. tudes* and *S. bigelowi* in having—a high second dorsal fin with a short posterior lobe, and a relatively large mouth placed well back in the head. The anterior margin of the hammer of the embryo of *S. mokarran* is nearly straight across and the groove in the front edge is a fine line quite unlike the prominent deep groove of *S. bigelowi* or the shallow indistinct groove of *S. tudes*. The eyes of the embryo of *S. mokarran* are large, about 2.6 per cent of the total length. The anal fin is hooked at its apex and its origin is only slightly in advance of the origin of the second dorsal.

TABLE 1.—MEASUREMENTS (IN MM) OF SPHYRNA BIGELOWI, N. SP. AND S. MOKARRAN (RÜPPELL)

Characters	*S. bigelowi*	*S. bigelowi*	*S. mokarran*
	Young male, U.S.N.M. No. 87682	Young male, U.S.N.M. No. 120751	Embryo female, U.S.N.M. No. 40026
Total length (in mm)	385	395	415
Length upper caudal lobe	115	118	130
Greatest width hammer	122	125	102
Greatest length hammer	61	64	43
Horisontal diameter orbit	6	6	10
Vertical diameter orbit	6	6	10
Width mouth	26	26	31
Internasal distance	89	91	73
Length nasal aperture	10	11	7
Tip of snout to:			
Front of mouth (length snout)	39	40	32
First gill opening	75	80	78
Base pectoral	97	97	90
Anus	172	180	200
Origin first dorsal	124	128	126
First dorsal fin:			
Anterior margin	64	63	70
Posterior margin	16	17	14
Base	37	37	40
Interdorsal distance	82	79	86
Second dorsal fin:			
Anterior margin	18	19	24
Posterior margin	17	18	21
Base	16	17	20
Pectoral fin:			
Anterior margin	50	52	48
Inner margin	20	21	17
Base	20	19	20
Anal fin:			
Anterior margin	21	20	22
Posterior margin	12	14	17
Base	32	31	24